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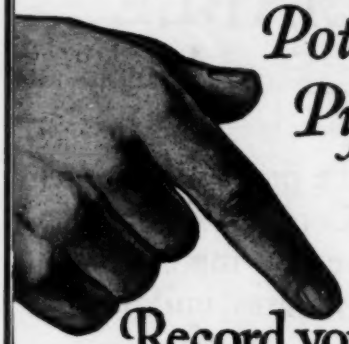

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ORIGINAL PAPERS

RELATIONSHIP BETWEEN CHEMICAL COMPOSITION AND THE THERMAL EXPANSION OF GLASSES[1]

By S. English and W. E. S. Turner

ABSTRACT

Thermal expansion data on soda-silica, soda-lime-silica, soda-magnesia-silica, soda-lime-magnesia-silica, soda-alumina-silica, soda-lime-alumina-silica, and other glasses, over the range of 25° to 90°C are presented and compared. The relations existing between thermal expansion and chemical composition of the glasses, with the exception of boric oxide glasses, is approximately linear. New so-called expansion factors calculated by the authors give calculated values for expansion coefficients closer to those observed than do Winkelman and Schott factors.

During the last eight years systematic investigations have been carried on in the Department of Glass Technology involving the measurement of several properties of glasses in relation to their composition, including that of thermal expansion. The work has reached such a stage that it may now be profitable to review what has been accomplished and to extract such generalizations as may legitimately be made. To assist in the survey, we have collected in Table I the results of our own measurements, which include both previously published, and new results, for several series of glasses.

The temperature range of our determinations of the thermal expansion is approximately 25 to 90°C, and it must be clearly understood that all the generalizations and the factors given in this paper refer to this particular temperature range. The method employed through-

[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., February, 1927. (Glass Division).

out was the dilatometric method, using the expansion of mercury in glass to determine the expansion of the latter. The details of the method have already been stated in our previous papers.[1]

The first question arising out of the results concerns the type of relationship which exists between the thermal expansion and the chemical composition of the glasses; and it appears that, for the ranges of composition we have investigated, this relationship is, with the exception of the boric oxide glasses, simple, and, in fact, approximately linear.

Figures 1 and 2 serve to illustrate this point. In Fig. 1, we have in graphical form the relationship between thermal expansion and compo ition for three series of glasses built up on the percentage basis, namely, (1) soda-silica glasses $(100-x)\%$ SiO_2 $x\%$ Na_2O, (2) soda-alumina-silica based on $(80-x)\%$ SiO_2 20% Na_2O $x\%$ Al_2O_3, and (3) soda-boric oxide-silica glasses of general composition $(80-x)\%$ SiO_2 20% Na_2O $x\%$ B_2O_3. For the first of these series, *i.e.*, the soda-silica, the curve deviates only slightly from the straight,[2] for the second, allowing for the fact that only four points are available and for the further fact that the soda content of the second glass of the series deviates more than that of any of the others from the mean value, it also seems reasonable to draw a straight line as representative of the series. The boric oxide glasses depart from the general relationship true of other glasses tested. The series depicted in Fig. 1 show a minimum point and this seems generally to be true for other series of boric oxide glasses.

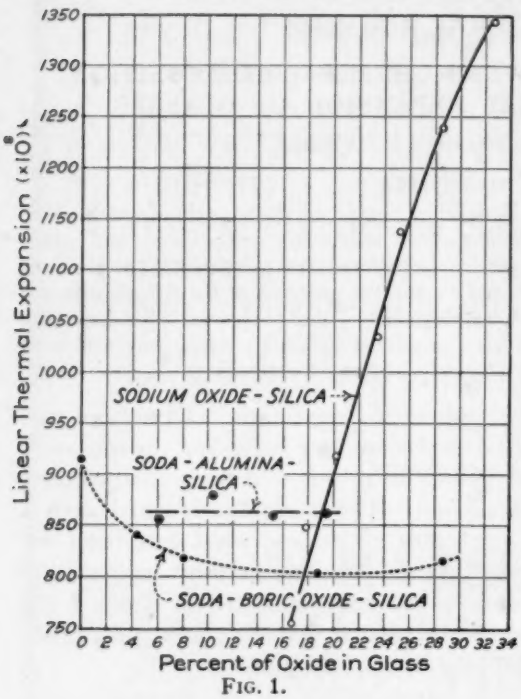

FIG. 1.

[1] *Jour. Soc. Glass Tech.*, **3**, 238 (1919).

[2] The more recent results, over a wider range of composition than our own, of M. Samsoen, *Compt. rend.*, **183**, 285, (1926), also lie on a curve which deviates only slightly from a straight line.

A point may here be emphasized in regard to the effect on the form of the curve of departures from the general composition of some member or members of the series. Although in quite a number of published investigations, the physical property value is plotted against the composition calculated from the batch formula, this is a procedure which is very risky. Particularly is this so in the case of thermal expansion, especially if the variation from the normal be due to one of the alkaline oxides. Soda and potash exert such a dominating effect on the expansion of the glass that slight variations, in some glasses of considerably less even than 1%, may cause a considerable variation in the thermal expansion. One of the points in the boric oxide series lies well away from the curve for this reason. Again, with the zinc oxide glasses of the series 6 SiO_2 $(2-x)$ Na_2O x ZnO, the influence of both silica and zinc oxide is so small compared with soda, that an attempt to get a graph which means anything is fruitless. We can only assume that glasses of this series probably fall into line with those containing similar chemical oxides, namely, lime and magnesia.

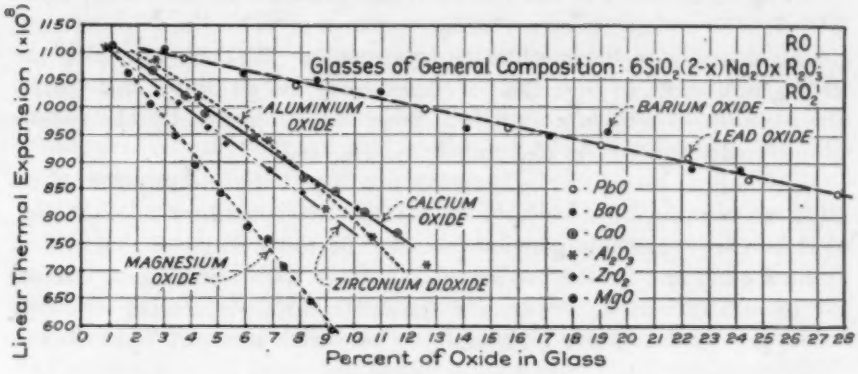

FIG. 2.

Figure 2 represents, graphically, the relationship between expansion and composition for all glasses, with the exception of those containing zinc oxide already referred to, constituted approximately according to the formula 6 SiO_2, $(2-x)$ Na_2O x RO, R_2O_3 or RO_2. The curves for the lead oxide and barium oxide glasses are identical and perfectly straight. Straight lines also connect up all the points for the lime, magnesia, and zirconia glasses. The curve for the alumina glasses deviates slightly from the straight, but as a first approximation we may consider it straight in any attempt to derive constants.

For the odd series in the appended tables to which no reference has so far been made, we have not attempted to plot a graph because of the scarcity of the points available, or, in the case of the soda-lime-

magnesia-silica glasses because of the deviation of composition somewhat from the parent type.

The evidence adduced seems to justify the view, held since Winkelmann and Schott stated their additive rule, that the relationship between thermal expansion and composition is approximately linear, at least for glasses of similar composition, the boric oxide glasses being an exception, however. While future investigation may reveal the existence of other series of glasses containing minima or maxima in the thermal expansion[1] we can only deal here with known data; and in the absence of any good reason to the contrary, we have worked on this simple relationship, namely,

$$3\alpha = ap, + bp_2 + cp_3 + \cdots$$

as given by Winkelmann and Schott and have recalculated the values to be assigned to the constants a, b, c, etc., (3α being the cubical expansion and p, p_2, p_3, etc., being the percentages of each oxide in the glass).

We have assumed at the outset of our calculations that silica takes with it into a glass its own thermal expansion. This, on our showing, does not apply to boric oxide or to zirconia. *We recognize that our assumption must be regarded as tentative to be tested by still further investigation.* The assumption was, however, supported by the results of our measurements on sodium silicate glasses.[2]

With silica, therefore, as starting point and the assumption of an additive relationship, we have calculated the constants a, b, c, etc., that is, the so-called expansion factors. As the well-known factors of Winkelmann and Schott are invariably given with reference to cubical expansion, our own figures are also quoted in this form. In the following table, our constants are given side by side with those of Winkelmann and Schott.

Oxide	English and Turner	Winkelmann and Schott
Silica	0.15×10^{-7}	0.8×10^{-7}
Soda	12.96 "	10.0 "
Potash	11.7 "	8.5 "
Lime	4.89 "	5.0 "
Magnesia	1.35 "	0.1 "
Alumina	0.52 "	5.0 "
Baryta	5.2 "	3.0 "
Lead oxide	3.18 "	3.0 "
Zinc oxide	0.21 "	1.8 "
Zirconia	0.69 "	2.1 "†
Boric oxide	−1.98§ "	0.1 "

§ Mayer & Havas, *Sprechsaal*, **44**, 188 (1911).

† Calculated only for the portion of the curve lying between 0 and 12% of boric oxide.

[1] Such as occur, for example, for several of the mechanical properties investigated by Gehlhoff and Thomas, *Z. tech. Phys.*, **8**, 105 (1926).

[2] *Jour. Soc. Glass Tech.*, **5**, 121 (1921).

It will be observed that there are important differences between the factors or constants of Winkelmann and Schott and our own. The value for boric oxide is recorded by us as negative. This figure has been worked out only for the portions of the thermal expansion curve which lie between 0 per cent B_2O_3 and the value at which the curve begins to bend toward a minimum. In other words it applies only to the initial approximately straight portion. For higher percentages of boric oxide the constant must obviously undergo variation.

The value for potassium oxide must be regarded as tentative. It has been calculated from the results of the measurements[1] made in this Department by the same method on a series of boric oxide-containing glasses of which Kavalier's glass was the parent. At some later stage it is likely that a series of simpler potash-containing glasses will be prepared and measured by us so that this constant can be checked.

The tables which are appended to this paper indicate the measure of success with which the linear coefficient of thermal expansion can be calculated from the above constants. The tables contain first of all the composition of the glasses determined by analysis and in the three other columns the observed value of the linear expansion coefficient and the calculated values, calculated in the first place on the basis of the above new constants and in the second on the basis of the constants previously given by Winkelmann and Schott.

It will be seen that throughout the series the values calculated by our new factors very much more closely correspond to the observed values than those based on Winkelmann and Schott's. In the case of the soda-silica glasses the calculations based on our own factors are closer to the observed values than are those of Winkelmann and Schott in 5 cases out of 7; in the soda-lime-silica glasses in 10 cases out of 12; in the soda-magnesia-silica glasses 10 out of 11; in the soda-lime-magnesia-silica glasses 6 out of 7; in the soda-alumina-silica glasses 12 out of 13; in the soda-lime-alumina-silica glasses 3 out of 3; in the soda-zinc oxide-silica glasses 6 out of 7, with the seventh almost identical; in the soda-baryta-silica glasses 9 out of 9; in the soda-lead oxide-silica glasses 5 out of 8; in the soda-zirconia-silica glasses 10 out of 12; in the soda-magnesia-zirconia-silica glasses 3 out of 5, the other two being practically identical; in the soda-boric oxide-silica glasses our own constants give better results over the initial straight portion of the curve but after the bend towards the minimum naturally they diverge; in the soda-potash-lime-boric oxide-silica glasses 6 cases out of 7, until the curve changes direction.

[1] Turner and Winks, *Jour. Soc. Glass Tech.*, **9**, 389 (1925).

We would naturally expect this greater accuracy with our own constants, because they have been deduced from the series of glasses in question. A more severe test is undoubtedly the application of these new factors to miscellaneous glasses. On searching for thermal expansion measurements for the temperature range 25 to 90°, or thereabouts, we find that the trustworthy data are much fewer than we had anticipated, and our tests have had to be confined to 8 glasses only. These are the glasses which were quoted by Hovestadt in his "Jena Glass,"[1] and we repeat them in Section B of the table, together with the observed and calculated expansions. The compositions recorded by Hovestadt are clearly not derived from the analysis of the glasses but only from the batch mixture employed; and this lack of preciseness in the composition renders impossible a precise comparison of observed and calculated expansions. It will be seen, however, that in 7 cases out of 8 the results of our own calculations are more in accordance with the observed values than are those based on Winkelmann and Schott's factors.

Finally, in introducing these new factors to the consideration of glass technologists, we would again remark that we regard them as tentative, liable to correction and improvement at a later date just like all other physical constants. We do not claim them as of entirely universal application. To do so would involve a big assumption as to the constitution of glasses. For example, they do not apply to an unusual glass like fused zinc silicate, although Winkelmann and Schott factors do show close concordance with the observed value. Again, for Pyrex glass, the calculation by Winkelmann and Schott's gives much closer results than by our own constants. The divergence in this latter case is quite likely connected with the problem of the change in the effect of boric oxide which occurs, as we have already shown, after a certain percentage has been added to the glass. Further, we have obtained less satisfactory calculated results in the case of glasses containing only moderate or small percentages of sodium oxide, that is, in the neighborhood of 10% or less of sodium oxide. This point requires further investigation. It may be found desirable to work out new constants for different ranges of silica or of alkali content; and, indeed, it may be necessary for this to be done so long as our knowledge of glass remains empirical. There is no doubt, however, of the practical value of constants such as the above and those presented in this paper have this merit, namely, that they have been derived from glasses of compositions similar in range to many commercial glasses.

[1] Hovestadt, Jena Glass, pp. 146, 147, and 216.

Appendix

A. Measurements Conducted in the Department of Glass Technology.

Soda-Silica Glasses*

Glass No.	Composition SiO_2	Na_2O	Fe_2O_3	Al_2O_3	CaO	Linear Expansion Coefficient $\alpha \times 10^6$ Observed	Calculated (English and Turner)	Calculated (Winkelmann and Schott)
448	66.91	32.74	0.05	0.07	0.04	1346	1442	1272
449	70.38	28.84	0.07	0.37	0.04	1240	1276	1157
1	74.05	25.34	0.14	0.24	0.21	1138	1131	1052
450b	76.27	23.51	0.08	0.12	0.22	1035	1053	986
479	79.13	20.34	0.07	0.29	0.04	917	915	896
480	81.34	17.96	0.06	0.17	0.04	849	814	820
481	82.83	16.98	0.08	0.28	0.02	755	775	793

* English and Turner, *Jour. Soc. Glass Tech.*, **5**, 121 (1921).

Soda-Lime-Silica Glasses.*

$6SiO_2(2-x)Na_2O \cdot xCaO$

Glass No.	Composition SiO_2	Na_2O	CaO	MgO	Al_2O_3	Fe_2O_3	As_2O_3	Linear Expansion Coefficient $\alpha \times 10^6$ Observed	Calculated (English and Turner)	Calculated (Winkelmann and Schott)
2	73.92	23.80	1.50	trace	0.20	0.14		1106	1109	1036
3	74.08	23.00	2.61	"	0.21	0.15		1065	1072	1013
4	74.07	21.50	3.81	"	0.28	0.14		1021	1039	993
5	73.78	20.78	4.50	0.15	0.38	0.19		988	992	981
6	73.18	19.38	6.26	0.21	0.58	0.61		947	966	958
7	74.41	17.20	7.45	0.24	0.30	0.40		911	907	916
8	74.99	16.00	8.16	0.26	0.31	0.09		870	873	886
9	74.96	14.88	9.36	0.28	0.42	0.16		844	835	862
10	74.59	14.22	10.38	0.30	0.45	0.21		810	812	850
11	74.93	13.02	11.68	0.31	0.38	0.17		769	770	822
16†	66.71	12.72	18.17	0.85	1.41	0.31	0.30	882	868	923
17†	69.73	11.22	17.38	0.55	0.50	0.25	0.47	801	802	789

* English and Turner, *Jour. Soc. Glass Tech.*, **3**, 238 (1919).

† These are glasses which have been used commercially. They do not belong to the general series and have not been plotted, therefore, in Fig. 2.

Soda-Magnesia-Silica Glasses*

$6SiO_2(2-x)\ Na_2O\ x\ MgO$

Glass No.	SiO_2	Na_2O	Composition MgO	CaO Al_2O_3 Fe_2O_3	Linear Expansion Coefficient $\alpha \times 10^6$ Observed	Calculated (English and Turner)	Calculated (Winkelmann and Schott)
24	74.07	24.23	1.10	0.37	1111	1088	1011
25	74.35	23.46	1.85	0.75	1064	1060	993
26	75.00	22.12	2.49	0.26	1005	1005	942
27	75.16	20.69	3.47	0.46	947	954	899
28	75.19	19.83	4.20	0.52	895	913	871
329	76.30	18.26	5.09	0.74	841	849	826
330	77.09	16.05	6.10	0.68	784	758	754
331	76.68	15.77	6.87	0.93	754	750	748
332	76.86	14.55	7.46	0.93	710	700	708
389	77.77	13.40	8.45	0.56	645	656	666
390	78.28	11.76	9.30	0.91	594	589	619

* English and Turner, *Jour. Soc. Glass Tech.*, **4**, 115 (1920).

Soda-Lime-Magnesia-Silica Glasses.*

$6SiO_2 1 \cdot 2Na_2O(0.8-x)\ CaO\ x\ MgO$

Glass No.	Composition SiO_2	Na_2O	CaO	MgO	Al_2O_3	Fe_2O_3	Linear Expansion Coefficient $\alpha \times 10^8$ Observed	Calculated (English and Turner)	Calculated (Winkelmann and Schott)
9	74.96	14.88	9.36	0.28	0.42	0.16	844	838	886
490	74.76	14.84	7.52	1.64	0.93	0.08	782	808	837
491	74.74	14.98	6.43	2.58	1.02	0.06	779	801	825
492	75.58	14.48	5.48	3.66	0.87	0.07	775	769	792
493	76.32	14.58	3.82	4.10	0.87	0.07	746	749	772
494	76.00	14.98	3.14	4.85	0.90	0.08	734	758	770
331	76.68	15.78	0.14	6.87	0.42	0.36	754	743	748

* English and Turner, *Jour. Soc. Glass Tech.*, **5**, 357 (1921).

Soda-Alumina-Silica Glasses*

Series $6SiO_2(2-x)\ Na_2O\ x\ Al_2O_3$

Glass No.	Composition SiO_2	Na_2O	Al_2O_3	Fe_2O_3	CaO	Linear Expansion Coefficient $\alpha \times 10^8$ Observed	Calculated (English and Turner)	Calculated (Winkelmann and Schott)
441*a*	74.30	22.68	2.72	0.07	0.08	1088	1056	1001
442	73.30	22.20	4.25	0.10	0.02	1020	998	1010
443d	72.05	20.62	6.85	0.08	0.12	939	938	997
444b	72.19	18.79	8.96	0.08	0.08	811	808	971
445d	72.27	16.61	10.71	0.07	0.21	764	773	929
446c	71.56	15.28	12.69	0.10	0.21	710	717	917
	Series $(80-x)\%\ SiO_2\ 20\%\ Na_2O \cdot x\%\ Al_2O_3$†							
680	75.12	18.22	6.46	0.08	0.16	854	836	919
682	70.76	18.56	10.49	0.09	0.09	877	853	985
681	66.17	18.08	15.54	0.08	0.12	861	838	1041
683	62.25	17.95	19.69	0.10	0.06	862	835	1095
	Series $(85-x)\%\ SiO_2\ 15\%\ Na_2O \cdot x\%\ Al_2O_3$†							
684	79.21	14.26	6.53	0.09	0.10	729	666	799
684a	74.72	14.71	10.64	0.05	0.10	723	688	869
685	69.99	14.43	15.50	0.07	0.09	727	682	929

Soda-Lime-Alumina-Silica Glasses.*

Series $6SiO_2\ 1.1\ Na_2O,\ (0.6+x)\ CaO,\ (0.3-x)\ Al_2O_3$

458	73.98	11.66	7.10	0.10	7.10	688	667	824
459	74.25	12.72	5.23	0.07	7.91	700	724	842
460	74.13	13.54	2.67	0.09	9.74	736	785	857

* English and Turner, *Jour. Soc. Glass Tech.*, **5**, 183 (1921).
† Dimbleby, English, Hodkin and Turner, *Jour. Soc. Glass Tech.*, **8**, 173 (1924).

Soda-Zinc Oxide-Silica Glasses

Series $6SiO_2\ (2-x)\ Na_2O,\ x\ ZnO$

Glass No.	Composition SiO_2	Na_2O	ZnO	Al_2O_3	Fe_2O_3	CaO	Linear Expansion Coefficient $\alpha \times 10^8$ Observed	Calculated (English and Turner)	Calculated (Winkelmann and Schott)
788A	74.09	24.07	1.29	0.68	0.04	0.04	1081	1087	1020
" B	73.48	21.89	3.51	0.77	0.07	0.06	1016	1008	962
" C	73.52	20.63	4.55	0.88	0.09	0.06	959	962	928
" D	73.36	19.48	6.12	0.88	0.06	0.04	917	923	898
" E	75.06	17.07	6.70	0.86	0.06	0.05	836	824	825
" F/2	72.11	17.20	9.54	0.89	0.04	0.08	878	848	840
" G/2	72.46	15.40	11.13	0.60	0.06	0.06	779	779	785

Soda-Baryta-Silica Glasses
Series $6SiO_2$ $(2-x)$ $Na_2O \cdot x$ BaO

Glass No.	Composition SiO_2	Na_2O	BaO	Al_2O_3	Fe_2O_3	Linear Expansion Coefficient $\alpha \times 10^6$ Observed	Calculated (English and Turner)	Calculated (Winkelmann and Schott)
798A	72.86	23.30	3.03	0.65	0.06	1102	1086	1013
" B	71.46	21.95	5.98	0.62	0.06	1065	1068	994
" C	70.83	20.11	8.59	0.55	0.06	1048	1025	955
" D	69.72	19.49	11.07	0.51	0.06	1034	1032	953
" E	68.33	17.39	14.16	0.38	0.05	962	984	907
" F/2	66.33	15.89	17.28	0.52	0.06	950	963	889
" G	64.94	14.98	19.38	0.87	0.07	956	951	882
" H/2	63.18	12.52	22.37	1.84	0.08	888	887	841
" I	62.67	11.72	24.25	1.23	0.06	884	879	822

Soda-Lead Oxide-Silica Glasses
Series $6SiO_2$ $(2-x)$ Na_2O, x PbO

Glass No.	Composition SiO_2	Na_2O	PbO	Al_2O_3	Fe_2O_3	Linear Expansion Coefficient $\alpha \times 10^6$ Observed	Calculated (English and Turner)	Calculated (Winkelmann and Schott)
804A	72.86	22.62	3.75	0.48	0.08	1090	1074	995
B	70.97	20.49	7.89	0.44	0.08	1041	1005	960
C	67.78	18.65	12.56	0.46	0.08	999	975	937
D	65.84	17.73	15.70	0.43	0.07	964	966	932
E	64.55	15.55	19.11	0.42	0.10	928	907	890
F	62.44	15.35	22.31	0.34	0.06	903	931	908
G	60.88	14.00	24.46	0.42	0.06	870	895	882
H	59.34	12.31	27.77	0.42	0.06	843	866	854

Soda-Zirconia-Silica Glasses
Series $6SiO_2$ $(2-x)$ $Na_2O \cdot x$ ZrO_2

Glass No.	Composition SiO_2	Na_2O	ZrO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	Linear Expansion Coefficient $\alpha \times 10^6$ Observed	Calculated (English and Turner)	Calculated (Winkelmann and Schott)
748A	73.77	24.70	0.95	0.47	0.08	trace	0.07	1106	1106	1035
" B	74.14	22.60	2.67	0.67	0.07	"	0.05	1028	1024	982
" C	72.80	22.15	3.54	1.33	0.08	0.09	0.05	1006	1005	981
" D	72.88	20.69	4.67	1.45	0.07	0.13	0.04	961	938	943
" E	72.96	20.12	5.39	1.36	0.09	0.15	0.05	935	920	928
" F	71.89	19.32	6.97	1.74	0.08	0.15	0.06	885	888	916
" G	71.97	18.90	8.25	0.82	0.09	0.18	0.06	844	873	896
" H	72.10	16.89	10.33	0.69	0.09	0.21	0.06	808	792	842
			Series $(6-x)$ SiO_2 $2Na_2O \cdot x$ ZrO_2							
757B	71.01	22.45	5.35	0.77	0.08	0.11	0.22	1015	1022	993
" C	65.59	21.40	11.13	1.20	0.09	0.23	0.23	935	982	996
" D	61.10	21.75	15.15	1.42	0.09	0.29	0.17	910	1010	1025
" 2	56.38	21.09	20.59	1.21	0.08	0.37	0.17	859	986	1025

* The factor for zirconia is that determined by Mayer and Havas, *Sprechsaal*, **44**, 188 (1911).

Soda-Magnesia-Zirconia Glasses
Series 72% SiO_2 20% $Na_2O \cdot (8-x)$% MgO $\cdot x$% ZrO_2

Glass No.	Composition SiO_2	Na_2O	MgO	ZrO_2	Al_2O_3	Fe_2O_3	TiO_2	Linear Expansion Coefficient $\alpha \times 10^6$ Observed	Calculated (English and Turner)	Calculated (Winkelmann and Schott)
803A/2	72.77	20.42	6.68	—	0.93	0.05	—	939	948	892
" B	72.47	18.50	4.96	1.83	2.27	0.09	0.07	871	866	862
" C	73.15	18.40	3.46	3.74	1.21	0.07	0.10	863	856	857
" D	72.36	19.11	1.83	5.95	0.45	0.05	0.12	849	883	881
" E	71.34	18.82	0.23	8.01	1.36	0.06	0.17	848	871	898

* Mayer and Havas, *Sprechsaal*, **44**, 188 (1911).

Soda-Boric Oxide-Silica Glasses[1]

Series $(80-x)\%\ SiO_2\ 20\%\ Na_2O \cdot x\%\ B_2O_3$

Glass No.	Composition SiO_2	Na_2O	B_2O_3	Al_2O_3	Fe_2O_3	CaO	Linear Expansion Coefficient $\alpha \times 10^6$ Observed	Calculated (English and Turner)	Calculated (Winkelmann and Schott)
600	79.84	19.46	—	0.69	0.11	0.12	915	884	876
601	74.22	19.78	4.46	0.93	0.14	0.14	840	866	878
602	71.56	18.76	8.28	1.00	0.08	0.10	817	795	838
603	68.39	18.92	11.34	1.01	0.09	0.12	813	781	837
604	64.72	19.95	14.45	0.72	0.06	0.14	837	802	856
605	61.28	18.93	18.84	0.74	0.08	0.11	805	727	820
606	50.04	20.36	28.83	0.78	0.05	0.08	814	716	835
	Series $(90-x)\%\ SiO_2\ 10\%\ Na_2O \cdot x\%\ B_2O_3$								
610/2	74.91	11.26	12.45	0.89	0.05	0.10	578	445	596
609/6	70.75	9.79	18.71	0.82	0.07	0.10	498	338	537
611/2	67.18	10.26	21.81	0.88	0.07	0.13	497	336	546
612/2	61.94	11.19	25.82	0.84	0.11	0.14	521	347	555
613/2	57.87	9.55	31.26	0.98	0.09	0.09	542	239	502
614/2	52.11	10.20	36.17	0.89	0.11	0.10	557	232	509
615/2	46.30	10.44	42.33	0.80	0.10	0.08	570	—	502
616/2	41.29	11.49	46.07	0.80	0.10	0.13	606	—	526

[1] English and Turner, *Jour. Soc. Glass Tech.*, **7**, 155 (1923).

Soda-Potash-Lime-Boric Oxide-Silica Glasses[1]

Series $(75 \cdot 82-x)\%\ SiO_2\ 6.86\%\ Na_2O \cdot 7.9\%\ K_2O \cdot 8.56\%\ CaO \cdot x\%\ B_2O_3$

Glass No.	Composition SiO_2	Na_2O	K_2O	CaO	B_2O_3	Al_2O_3	Fe_2O_3	Linear Expansion Coefficient $\alpha \times 10^6$ Observed	Calculated (English and Turner)	Calculated (Winkelmann and Schott)
755	75.82	6.86	7.90	8.56	0.0	0.59	0.07	802	783	808
" B	75.38	6.84	8.02	8.52	0.66	0.44	0.08	795	781	807
" D	75.38	6.14	9.38	8.40	2.05	0.65	0.07	785	793	824
" E	69.06	7.54	8.22	8.64	5.44	0.91	0.08	746	787	831
" F	68.20	7.00	7.56	8.70	7.90	0.65	0.09	734	721	790
" G	66.50	7.04	7.40	8.72	9.58	0.65	0.09	714	706	783
" H	64.58	7.50	7.42	8.60	10.78	0.91	0.09	701	716	796

[1] Winks and Turner, *Jour. Soc. Glass Tech.*, **9**, 389 (1925).

B. Miscellaneous Glasses

Observer	Temperature Interval °C	Glass Composition SiO_2	B_2O_3	ZnO	BaO	Na_2O	K_2O	PbO	CaO	Al_2O_3	Linear Expansion Coefficient $\alpha \times 10^6$ Observed	Calculated (English and Turner)	Calculated (Winkelmann and Schott)
Winkelmann (59)	0–100	73.2	—	—	—	18.5	—	—	8.0	—	967	965	947
Theisen, Scheel and Sell (6) (16III)	0–100	67.3	2.0	7.0	—	14.0	—	—	7.0	2.5	769	748	881
Pulfrich (47)	12.9–97.6	54.3	1.5	—	—	3.0	8.0	33.0	—	—	793	808	803
Pulfrich (54)	9.9–93.3	51.7	—	7.0	20.0	1.5	9.5	10.0	—	—	900	852	800
Pulfrich (55)	15.6–94.2	68.2	—	2.0	—	16.5	—	13.1	—	—	903	887	877
Pulfrich (56)	17.9–97.2	68.1	3.5	7.0	—	5.0	16.0	—	—	—	917	856	847
Pulfrich (60)	17.0–95.5	65.5	2.5	2.0	9.6	5.0	15.0	—	—	—	963	953	877
Straubel (63)	0–100	54.8	—	—	—	6.0	11.5	25.0	—	2.5	1017	1004	963

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SOME THERMAL CHARACTERISTICS OF CLAYS[1]

By A. Ernest MacGee

ABSTRACT

The literature pertaining to thermal reactions, specific heats, and thermal conductivities of clays is reviewed and discussed, particular attention being given to the heat required to fire various clays. All clays undergo an endothermic reaction between 100°C and 650°C amounting to from 30 to 150 calories per gram. An exothermic reaction takes place at about 950°C which evolves from 10 to 40 calories per gram. The specific heats of clays and shales are about .45 over the interval 20°C to 1100°C.

Introduction

Clays are very complex minerals or mineral aggregates, and as would be expected, exhibit intensely interesting thermal phenomena on heating. The thermal processes which clays and ceramic bodies undergo on being heated to temperatures as high as 1200°C have been rather extensively investigated and have been found to be quite complex. However, both qualitative and quantitative information along this line is distinctly inadequate for the higher temperatures—especially so in the case of the various types of ceramic bodies.

Thermal Reactions

The thermal reactions occurring in clays on heating were first examined by Le Chatelier[2] in 1887 and his preliminary survey has since been extended and elaborated upon by a number of other investigators. Mellor and Holdcroft[3] determined from time-temperature curves, obtained by a differential thermal method, that kaolinite underwent an endothermic reaction just above 500°C, reaching a maximum at 600°C, decomposing into water, silica, and alumina. Exothermic reactions occurred at about 800, 900, and 1200°C, sillimanite being formed by a recombination of the silica and alumina at about 1200°C. They found that purified china clay had the same time-temperature curve as that of crystalline kaolinite, both showing no definite temperature of dehydration but, rather, losing their water continuously as the temperature was increased. However, most of the water was evolved between 400 and 600°C. They found the heat of decomposition of the kaolinite molecule at 500°C to be about 42 calories. The latent heat of transformation at about 800°C, probably due to a polymerization of the alumina, was about 22 calories. Ashley[4]

[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., February, 1927. (Heavy Clay Products Division.)

[2] H. Le Chatelier, *Bull. Soc. Min.*, **10**, 207 (1887); *Z. physik. Chemie*, **1**, 396 (1887).

[3] J. W. Mellor and A. D. Holdcroft, "The Chemical Constitution of the Kaolinite Molecule," *Trans. Ceram. Soc.* (Eng.), **10**, 94–120 (1910–11); *ibid.*, **11**, 169–173 (1911–12).

[4] H. E. Ashley, "The Decomposition of Clays, etc.," *Ind. Eng. Chem.*, **3**, 91–94 (1911).

determined from time-temperature curves that many clays undergo an endothermic process which extends to about 600°C. Some of his data are shown in Table I. Other qualitative work of this nature has

TABLE I

HEAT RETARDATIONS AND ACCELERATIONS OF VARIOUS CLAYS

Material	End of Retardation	Acceleration
Albany slip clay	590°C	
English china clay	575, 582, 574	940°C
N. C. kaolin	578	
No. 1 fine clay	592	
No. 2 fine clay	597	
English ball clay	581	
Shale	583	900 to 970
Tenn. No. 3 ball clay	583	
N. J. sagger clay	612	

NOTE: Retardations indicate endothermic reactions while accelerations indicate exothermic reactions.

been carried out by Wallach,[1] Rieke,[2] Satoh,[3] Brown and Montgomery,[4] Klein,[5] Sokoloff,[6] and others. In the case of china clay, Satoh assumes that the exothermic reaction at 900°C was due to a polymerization of the alumina while that at 1200 and 1300°C was due to the formation of amorphous sillimanite. Sokoloff found that some water was lost at 100°C followed by an ever-increasing amount as the temperature was raised until it reached a maximum between 600 and 800°C after which there was practically no loss.

Houldsworth and Cobb[7] have probably given the most accurate data on the loss in weight of clays on heating. They could detect a loss in weight of .005 gram while the clay sample was being heated. Kaolin lost .8% of its weight on heating an air-dried sample to 130°C, after which there was little loss in weight as the temperature was slowly raised to 425°C. Although the sample continually lost weight to 850°C, it could be made to lose 11% (nearly all of the water of hydration) of its weight if the temperature were raised from 425 to 450°C over a period of ten days. They found that all the clays and shales investigated showed a heat absorption between 500 and 630°C and a heat evolution at both 960 and 1030°C.

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[1] R. Wallach, *Compt. Rend.*, **157**, 48–50 (1913).

[2] R. Rieke, "Einige Beobachtungen über den Gluhverlust von Kaolinen und Tibeb," *Sprechsaal*, **44**, 637–840 (1911).

[3] S. Satoh "A Study of the Heating and Cooling Curves of Japanese Kaolinite," *Jour. Amer. Ceram. Soc.*, **4**, 182–94 (1921).

[4] Brown and Montgomery, Bur. Stand., *Tech. Paper*, No. 21 (1913).

[5] A. A. Klein, Bur. Stand., *Tech. Paper*, No. 80 (1916).

[6] A. M. Sokoloff "Zur Frage des Molekularem Zerfalles des Kaolinite im Anfangsstadium des Gluhens," *Tonind. Ztg.*, **36**, 1107–10 (1912).

[7] H. S. Houldsworth and J. W. Cobb, "The Behavior of Fire Clays, Bauxites, etc.. on Heating," *Trans. Ceram. Soc.* (Eng.), **22**, 111–37 (1922–23).

From the foregoing references, it is apparent that the thermal reactions which pure clays, such as English china clay, undergo on heating are quite involved. It is generally accepted that the endothermic reaction at about 550°C is due to the driving off of the chemically bound water and the decomposition of the clay molecule or aggregate. However, the chemical significance of the exothermic reaction at about 1000°C is not definitely known. More work along this line is urgently needed and it would seem that the microscope and the X-ray are the tools with which the problem can be most successfully attacked. In addition to the thermal phenomena exhibited by the actual clay aggregate, most all of the alluvial clays, fire clays, shales, etc., contain materials which of themselves undergo thermal changes and thereby further complicate the thermal behavior of the mass on heating. Many of the thermal changes which clays undergo on heating are not reversed on cooling, such as the decomposition of carbonates, sulphates, hydrates, etc. In addition to the thermal processes accompanying the various chemical reactions, there are often physical reactions that involve thermal changes such as the transformation of one allotropic modification into another, the latent heat of fusion, and the solution of solid constituents by a melt. Furthermore, most clays and shales contain carbonaceous matter and sulphur in one form or another, which is largely burned out during the firing process. When the various clays and shales are fired, heat is absorbed, the net quantity depending largely upon the heats of reaction resulting from the chemical and physical changes which accompany the firing process. Of course, exothermic reactions help to raise the temperature of the materials and lessen the heat absorbed from some external source while endothermic reactions require an additional amount of heat from some external source in order to complete them.

Specific Heat Phenomena

Before one can say how much heat is required to heat a given mass of clay or shale to any given temperature, it is essential that the interval specific heats of the material be known. By interval specific heat is meant the number of calories per degree which must be added from some external source in order to raise the temperature of one gram of material from, 0 to t°C. The determination of the interval specific heats of clays and shales is greatly complicated owing to the fact that many of the thermal changes which they undergo on heating are not reversed on cooling. That is, they do not absorb the same amount of heat on being heated as they evolve on being cooled. Navias[1]

[1] L. Navias, "Measurement of the Heat Absorbed and Evolved by Clays during Firing and Cooling," *Jour. Amer. Ceram. Soc.*, **6**, 1268–98 (1923).

has shown that Tennessee ball clay absorbed .51 calories per gram per degree on being heated from 900 to 1200°C while it only evolved .20 calories per degree on cooling through this interval. On the other hand, A-1 English china clay, because of a violent exothermic process, only absorbed about .08 calories per gram per degree on being heated from 900 to 1200°C while it evolved .17 calories per degree in cooling through this interval. Therefore, any method which is to be employed for the determination of interval specific heats of clays and shales must be of such a nature as to account for any and all thermal changes which they may undergo on heating.

The law of Dulong and Petit states that the product of the specific heat and the atomic weight of the solid elements is constant. The value of this constant, called the atomic heat, is approximately 6.4. Neumann[1] showed that a similar relation held for compounds of the same general character, while Kopp[2] pointed out that the thermal capacity of the atoms was not appreciably altered when they entered into chemical combination. That is, the molecular heat of solid compounds is an additive property, being made up of the atomic heats of the constituent elements. Therefore, if the molecular formula of the compound is known, its specific heat can be calculated. It is impractical to do this in the case of clays and shales because of their undergoing thermal reactions which cannot be accounted for.

The method of mixtures in one modification or another has been extensively used in the past for determining specific heats. This involves heating the weighed unknown to the temperature in question and allowing it to fall into a calorimeter. Thus, the quantity of heat it contained at the time of dropping can be measured and its specific heat calculated. This method is based upon the assumption that the heat evolved on cooling is equal to that absorbed on heating. However, this assumption is entirely unwarranted in the case of shales and clays. Knote[3] used this method and found that the specific heat of raw flint fire clay was .2 over the interval of about 20 to 1050°C, a value which subsequent work has shown to be entirely too low.

Navias,[4] who used a modification of the calorimetric method, and Cohn,[5] MacGee,[6] and Simpson,[7] who used differential thermal

[1] Neumann, *Pogg. Ann.*, **23**, 1 (1831).

[2] Kopp, *Lieb. Ann. Suppl.*, **3**, 5 (1864).

[3] Knote, "Note on the Specific Heat of Clay," *Trans. Amer. Ceram. Soc.*, **14**, 394–98 (1912).

[4] Navias, *loc. cit.*

[5] W. M. Cohn, "The Problem of Heat Economy in the Ceramic Industry," *Jour. Amer. Ceram. Soc.*, **7**, 359–76, 474–88, 548–62 (1924).

[6] A. Ernest MacGee, "The Heat Required to Fire Ceramic Bodies," *Jour. Amer. Ceram. Soc.*, **9**, 206–48 (1926).

[7] H. E. Simpson, "The Heat Required to Fire Ceramic Bodies." Thesis presented to The Ohio State University for the degree of Master of Science.

TABLE II

GENERAL THERMAL REACTIONS OF CLAYS AND SPECIFIC HEATS OVER THE INTERVAL 20 TO 1100°C

Material	Authority	Endothermic Reaction	Exothermic Reaction	Specific Heat
Plastic fire clay	Simpson	82 cal/gr between 200 and 650°C	18 cal/gr at 945°C	.45
Burley flint fire clay	"	73 " " " " " "	15 " " " "	.45
Smooth flint fire clay	"	100 " " " " " "	30 " " " 970	.50
Semiflint fire clay	"	115 " " " " " "	25 " " " 965	.50
Flint fire clay	Navias	Completed at 600°C	Between 900 and 1200°C	.49
Missouri diaspor clay	MacGee	100 cal/gr between 100 and 600°C	None	.45
Missouri diaspor clay	Simpson	75 " " " 250 " 650	13 cal/gr at 990°C	.44
Ky. ball clay	MacGee	90 " " " 100 " 600	5 " " " 975	.45
Tenn. " "	Navias	Completed at 600°C	None	.50
Bedford shale	Simpson	45 cal/gr between 100 and 625°C	10 cal/gr at 940	.46
Allegheny shale	"	57 " " " 150 " 600	10 " " between 935 and 980°C	.45
Indiana shale	"	32 " " " 200 " 650	12 " " " 910 " 1015	.45
Peoria, Ill. surface clay	"	35 " " " " " "	10 " " " 900 " 1000	.44
Cleveland, O. surface clay	"	37 " " " " " 625	5 " " " 925 " 1000	.44
A-1 English china clay	MacGee	123 " " " 100 " 600	35 " " at 970°C	.48
A-1 English china clay	Navias	Completed at 600°C	Between 900 and 1200°C	.50
N. C. kaolin	"	" " "	" " " "	.49
N. C. kaolin	MacGee	150 cal/gr between 100 and 600°C	40 cal/gr at 970°C	.50
Zettlitz kaolin	Cohn	92 " " " 450 " 625	16 " " " 965	.40
Georgia kaolin	MacGee	128 " " " 100 " 600	23 " " " 980	.49
Florida kaolin	"	123 " " " " " "	10 " " " "	.48
Kaolinite	Mellor	42 " " at 500°C	22 " " " 800°C	

methods, have obtained data for the interval specific heats of clays which more or less adequately accounted for all of the thermal processes which the sample underwent on heating. The methods used by Cohn, MacGee, and Simpson showed the quantitative values for the more pronounced endothermic and exothermic reactions which the clays underwent on heating as well as the temperatures at which the reactions began and ended. Table II shows the general data obtained for the different types of clays by the several investigators, while Fig. 1 graphically illustrates some of the values for different types of clays. The quantitative values for the thermal reactions are read directly from the calory base line. The various thermal processes scarcely, if ever, present an exactly horizontal section of the curve and must, therefore, be extrapolated from the curve sections above and below the reaction in question. The method of doing this is illustrated by the dotted lines in Fig. 1, which show that kaolin undergoes an endothermic reaction between about 200 and 600°C which amounts to about 150 calories per gram. An exothermic reaction takes place at about 950°C which amounts to about 40 calories per gram.

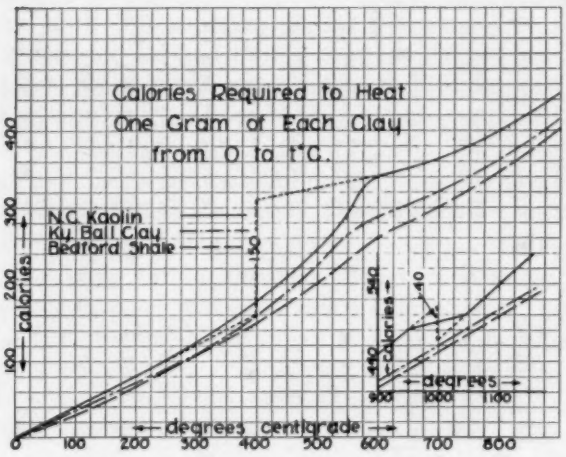

FIG. 1.

The thermal reactions in ball clay, surface clay, and shale are distinctly less intense than the corresponding reactions in kaolin. This is an important reason why shale absorbs considerably less heat on firing than the more perfect clay types, such as kaolin or smooth flint fire clay. Since the specific heat of shale is about .46 over the interval 20 to 1100°C, about 500 calories are required from the fuel to raise the temperature of one gram from 20 to 1100°C. The value for other temperatures may be obtained by referring to the curve in Fig. 1.

Although the specific heat data obtained by MacGee, Cohn, Navias, and Simpson for the same class of materials agree quite well in general, the values which Cohn obtained for clays are decidedly lower below 500°C than the corresponding values obtained by the other investi-

gators. Cohn found the specific heat of kaolin to be about .23 over the interval 20 to 400°C, while MacGee and Navias found it to be about .45 over this temperature range. The accuracy of the various methods is, of course, inherently greater for the higher temperatures but, from the information available in the literature, it appears that Cohn's values are too low. Thus, as determined by Simpson, the specific heat of Bedford shale is about .3 over the interval 20 to 100°C, about .38 over the interval 20 to 400°C, and about .44 over the interval 20 to 850°C. That is, about 24 calories are required to heat one gram of air dried shale from 20 to 100°C.

Quantity of Heat Required

In commercial operations, it is apparent that the quantity of heat required to heat a kiln of ware is not dependent solely upon the specific heat of the ware. The heat consumption is distributed over a number of sources, among which are the following:

1. One part is consumed in heating the ware to its maturing temperature. This quantity is largely dependent upon the interval specific heat which in turn depends upon the amount and intensity of the endothermic and exothermic reactions which take place during the heating process.
2. A portion is consumed in keeping the ware at the various temperatures for the desired length of time.
3. A portion is consumed in heating the kiln and covering the losses from convection, radiation, and conduction.
4. A portion is consumed in providing a satisfactory draft.
5. A portion is lost in combustible flue gases and ash.

However, if the specific heat is known, the actual quantity of heat absorbed by the ware can be calculated and the kiln efficiency, operating efficiency, etc., readily obtained. In this manner, Cohn has shown the percentage of fuel actually utilized in heating porcelain ware to a maturing temperature of about 1200°C to be as follows:

Circular kilns	2 to 3% of the fuel used
Gas compartment kilns	3 to 4% " " " "
Tunnel kilns	6 to 12% " " " "

MacGee has found the efficiency of periodic kilns to vary from 22 to 45% in firing various types of fireclay refractories, the final temperatures being about 1200°C. Simpson has found the efficiency of periodic kilns to vary from 20 to 30% in firing various types of heavy clay ware, such as common, face, and paving brick, and hollow tile.

Importance of Thermal Conductivity

Doubtless for all practical purposes, the interval specific heat values are the criterion for the amount of heat which a clay will

absorb. However, it is quite possible that two clays with the same specific heat—or the same clay for that matter—will cause the consumption of slightly different quantities of fuel even when fired under the same conditions. In the case of identical specific heats, the same quantity of heat will ultimately be absorbed. However, the time required to absorb the heat may vary considerably. This is true because the speed at which heat is absorbed depends not only upon the specific heat but also upon the thermal conductivity and the specific gravity. The rate of heat absorption or thermal diffusivity,

$$d = \frac{K}{C \cdot S} \quad \text{in which}$$

C = specific heat
S = specific gravity
K = thermal conductivity
d = rise in temperature produced in one cubic centimeter of the substance by one calory flowing in one second through one square centimeter of a layer one centimeter thick, having a temperature difference of one degree Centigrade between its faces.

For example, assume that two brick have identical specific heats. The temperature at the surface may have to be maintained much longer before thermal equilibrium is reached in the case of the one than in the other because of differences in specific gravity and thermal conductivity. Of course, the longer a temperature must be maintained the greater will be the quantity of fuel consumed because of radiation, conduction, draft, and other losses.

Conclusions

1. Practically all clays undergo an endothermic reaction between 100 and 650°C, reaching a maximum at about 550°C, which absorbs from about 40 to 130 calories per gram of air dried material. This reaction primarily involves the driving off of the hygroscopic and chemically bound water and the decomposition of the clay molecule or aggregate, water, amorphous alumina and silica resulting.

2. Practically all clays undergo an exothermic reaction, the chemical significance of which is not definitely known, in the neighborhood of 950°C which evolves from about 5 to 30 calories per gram of air dried material.

3. The specific heats of practically all clays lie between .4 and .5 over the interval 20 to 1100°C. However, the specific heats vary from only .2 to .3 over the interval 20 to 100°C.

4. The fuel required to heat a given mass of clay depends not only upon the specific heat but, also, upon its thermal conductivity and specific gravity.

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SOME PHYSICAL PROPERTIES OF CHEMICAL STONEWARE BODIES[1]

By A. Ernest MacGee

ABSTRACT

Crushing, transverse and impact strength, thermal expansion, resistance to heat shock, and elasticity were determined for nine commercial chemical stoneware bodies. Although the thermal expansions were not widely different, great variations were obtained for the elasticity and crushing strength values of the various bodies. The elasticity and crushing strength of the more porous bodies were distinctly less than for the more vitreous bodies. The method of making and interpreting the impact test is discussed in detail.

Introduction

This investigation was carried out with the object of determining some of the physical properties which are characteristic of modern chemical stoneware bodies.

The test pieces employed in the investigation were kindly placed at the author's disposal by a well-known manufacturer of chemical stoneware. In order that the data obtained would be representative of this general type of ware, specimens representing nine different body compositions developed for different uses as chemical stoneware, were tested. All test pieces were hand-pressed, fired in open kilns and otherwise treated as though they had been made into regular commercial chemical stoneware articles.

Although the exact chemical and mineral composition of the bodies was not available, they were blended bodies consisting of from two to six different kinds of clays ordinarily employed in the manufacture of this type of ware. Although no grog was used in bodies *E* and *F*, all others had ground vitrified chemical ware grog of different meshes. Bodies *B* and *D* were characterized by an excessively high grog and silica content.

Each body was tempered with about 20% water. The test pieces were fired to cone 8 on a nine-day firing in the regular commercial kilns used to fire this type of ware. Table I shows some of the general characteristics of the various bodies.

Since the test-pieces represented nine different body compositions and were made under actual manufacturing conditions, the data herein presented offers an insight into several of the physical properties which are characteristic of modern chemical stoneware bodies.

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[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., Feb., 1927. (Heavy Clay Products Division.)

Crushing Strength

Test-pieces 1 by 1 by 2 inches were crushed on an Olsen Hydraulic Press of 200,000 pounds capacity, the pressure being applied over an area of approximately two square inches. In order to cushion the pressure and aid in making its application more uniform over the face of the piece, three layers of heavy cardboard were placed between the test-pieces and the pressure caps of the press. The average of six test-pieces was taken as the crushing strength value for each body.

TABLE I

CHEMICAL STONEWARE BODIES FIRED TO CONE 8 IN A 9-DAY FIRING

Body	Grog	Appearance of Ware
A	Coarse	Very porous and coarse-grained
B	"	Medium porosity " " "
C	Very coarse	Very low " " " "
D	Medium	" " " " fine-grained
E	No grog	" " " " " "
F	" "	" " " " " "
G	Fine	Practically vitreous and very fine-grained
H	Very fine	" " " " " "
I	" "	" " " " " "

Thermal Expansion

The coefficients of linear expansion were determined in an especially constructed apparatus at intervals of approximately 100°C from room temperature to about 850°C. Figure 1 shows a photograph of this apparatus. The furnace was designed to carry three 1 by 1 by 6-inch test-pieces so that three determinations were made at the same time. The apparatus consisted, essentially, of a nichrome wire wound furnace whose temperature was under control by means of a 300-ohm rheostat. Fused silica rods extended through the furnace cover and rested upon the tops of the respective test-pieces. The pinion of an Ames dial rested upon the top of the fused silica rod so that the combined movement of the rods and test-piece was recorded on the dial which was calibrated in thousandths of an inch, readings being estimated to within one-tenth of a division. The total expansion of the apparatus was carefully determined by standardizing it with a well-annealed 1 by 1 by 6-inch bar of fused silica in the place ordinarily occupied by the test-piece. The actual temperatures were determined potentiometrically by means of two thermocouples, the hot junctions being, respectively, at the center of the tops and bottoms of the three test-pieces. The cold junctions were at the temperature of melting ice. The coefficient of linear expansion was calculated as follows from the

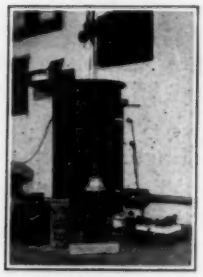

FIG. 1.

length of the test-piece and the amount it expanded when heated over the temperature interval in question, the initial temperature in every case being 30°C:

$$a = \frac{L - l}{l\,(t - 30)} \qquad \text{in which}$$

a = coefficient of linear expansion over the interval 30 to t°C
t = temperature in degrees C
l = length of test-piece at 30°C (room temp.)
L = length of test-piece at the temperature, t

The temperature was held constant for 20 minutes at each temperature, t, in order to insure a uniform temperature in the test-pieces. The furnace temperatures were duplicated in the different determinations to within 10°C. Table II shows the coefficient of expansion data, the average of four test-pieces being taken as the linear coefficients of expansion for each body.

Transverse Strength

Transverse strength was determined by means of an especially constructed apparatus on 1 by 1 by 6-inch test-pieces. Figure 2 shows a photograph of this apparatus which was designed to break the piece on a 5-inch span, the pressure being applied at the rate of about 60 pounds per minute. Pressure was applied by allowing small shot to flow from the container on top of the table into the bucket suspended from the beam, the apparatus being so constructed that the flow of shot was stopped the instant the test-piece broke. The apparatus was sensitive to about one-fourth of one per cent of the pressure applied to the test-piece.

FIG. 2.

The average of ten test-pieces was taken to determine the modulus of rupture for each body, the value being calculated according to the following formula:

$$M = \frac{3 \times P \times L}{2 \times b \times d^2}$$ in which

M = modulus of rupture
P = pressure applied to test-piece
L = distance between knife edges
b = breadth of test-piece
d = depth of test-piece

Elasticity

Elasticity was determined on 1 by 1 by 6-inch test-pieces by means of the apparatus shown in Fig. 2. This value was determined on a 5-inch span, the pressure being applied at the rate of about 60 pounds per minute. The plane of the lower knife edges remained constant during a determination. As pressure was applied to the stirrup or top knife edge, the test-piece was bent downward. The amount the test-piece bent was determined by noting the deflection on an Ames dial calibrated in thousandths of an inch. The pinion of the dial rested upon the top knife edge. In order to reduce to a minimum the error caused by the taking up of slack in the apparatus, a pressure of 25 pounds was applied to the piece before the initial reading of the dial was taken. It is essential that the surfaces of the test-piece in contact with the knife edges be perfectly level and parallel, otherwise an incorrect deflection will be obtained due to turning of the piece on the knife edges. The average of ten test-pieces was taken to determine Young's modulus of elasticity which was calculated as follows:

$$E = \frac{m \times l^3}{4 \times S \times b \times d^3}$$ in which

E = Young's modulus of elasticity
m = pressure applied to test-piece
l = distance between knife edges
s = bending of test-piece in inches
b = breadth of test-piece
d = depth of test-piece

Heat Shock

The resistance of the various bodies to sudden temperature change is expressed as the percentage decrease in impact strength after a definite heat-shock treatment. The heat-shock treatment consisted of quenching the test-pieces (1 by 1 by 2 inches) in water at room temperatures from an electric furnace temperature of 400°C ± 10°C. After quenching, the pieces were allowed to steam in the air for one minute after which they were again placed in the furnace. This alternate heating and cooling was repeated ten times. After this heat-shock treatment, the resistance of the pieces to sudden mechanical shock was determined as described under "Impact Strength." Knowing

the original impact strength of duplicate test-pieces, heat shock was calculated as follows:

$$h = \frac{R-r}{R} \times 100 \text{ in which}$$

h = resistance to heat shock
R = impact strength before heat shock
r = " " after " "

The average of six test-pieces was taken as the heat-shock value for each body. As determined in this test, low heat-shock values are desired as this shows better resistance to sudden and repeated temperature change. Likewise, low modulus of elasticity values are desired as the lower the modulus the greater the actual elasticity.

Impact Strength

The resistance of the bodies to severe mechanical shock was determined by means of the apparatus shown in Fig. 3. This was the regular Olsen impact machine in which a two-kilogram weight was allowed to fall successively one, two, three, etc., centimeters until the 1 by 1 by 2-inch test-piece was broken. In order to cushion the blow and help insure a more uniform surface, ten layers of ordinary newspaper were placed under the test-piece.

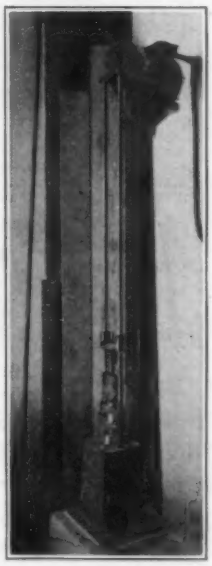

FIG. 3.

The impact test in one modification or another has been employed in the past by a number of investigators and in a number of laboratories. There has been remarkable inconsistency in evaluating this test and considerable confusion has arisen therefrom. So much so in fact that the test has fallen into disrepute with certain investigators. However, the test is very conveniently and quickly made and, when properly interpreted, is a valuable criterion for the general mechanical strength of a given test-piece. It practically goes without saying that test-pieces of a uniform size and shape must be used before comparable results can be obtained. Although this test is often made with an apparatus based on some modification of the pendulum principle, the usual type of apparatus operates on the principle of a weight falling vertically under the influence of gravity alone.

After a test-piece has broken, the question arises as to the correct manner of evaluating the impact strength of the piece in question. In many laboratories if a piece withstands eleven blows (the weight

falling on the piece from successive heights of one, two, three, etc., centimeters or inches as the case may be) it is said to have an impact strength of 11. Similarly, a piece breaking on the sixteenth blow would have an impact strength of 16. Obviously, the latter would possess considerably more resistance to impact than the former. The question is how much more. In many cases no effort is made to place a quantitative interpretation on the various values, simply saying that a piece breaking on the thirteenth blow is better than one breaking on the eleventh. It is apparent that each blow weakens the piece somewhat and some have, accordingly, taken the sum of the blows as the impact strength. Thus, a piece breaking on the sixth blow would have an impact value of 1+2+3+4+5+6 or 21. Of course, the weight of the hammer has considerable influence on the number of blows a piece will survive. Thus, some investigators have expressed impact strength in terms of inch-pounds, this value being the sum of the products of the respective distances of fall in inches times the weight in pounds, while others have expressed this value in terms of accumulated potential energy, etc.

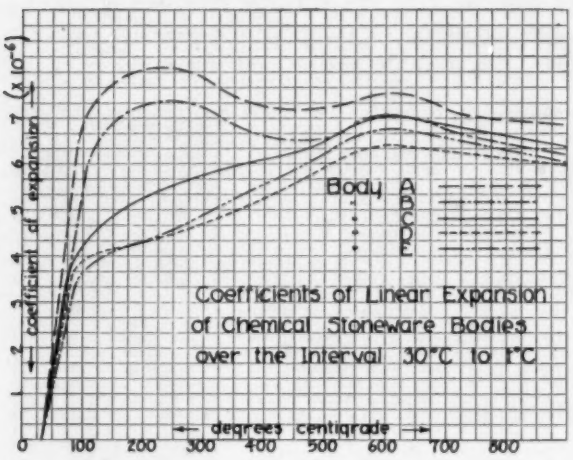

FIG. 4.

The severity of the blow is dependent primarily upon the momentum of the falling body at the instant of impact, it of course being assumed that the blow is always applied to the piece in the same manner, such as the pien end of a hammer. Thus, the shock of the blow is a function of the velocity of the falling body as well as its weight. Consequently, in the case of a weight falling successive distances, the severity of the shock increases with each succeeding blow. Thus, a piece breaking at twenty blows is considerably more than twice as resistant to impact as one breaking at ten blows.

Regardless of the manner in which the blow is applied to the test-piece, the impact strength of the specimen should be expressed in terms of momentum as gram centimeters at the instant of impact. In the case of a weight falling successive distances under the influence of gravity, the calculation is as follows:

(1) $t=(2d/g)^{\frac{1}{2}}$ in which
t = time required for weight to fall
d = distance weight falls in centimeters
g = gravitational constant or 980

(2) $V=at$ in which
V = velocity of falling weight at instant of impact
a = acceleration due to gravity or 980
t = time required for weight to fall

(3) $M=mv$ in which
M = momentum at instant of impact
m = weight of falling body
v = velocity of falling body at instant of impact

Thus, a piece which broke on the eighteenth blow (a two-kilogram weight falling successively one, two, three, etc., centimeters) has an impact strength value of 4.67×10^6, the value being the sum of the eighteen blows each being expressed in terms of momentum as gram centimeters as above explained. Similarly, a piece which broke on the ninth blow has an impact strength of 1.71×10^6 or considerably less than one-half of the value for the piece breaking on the eighteenth blow.

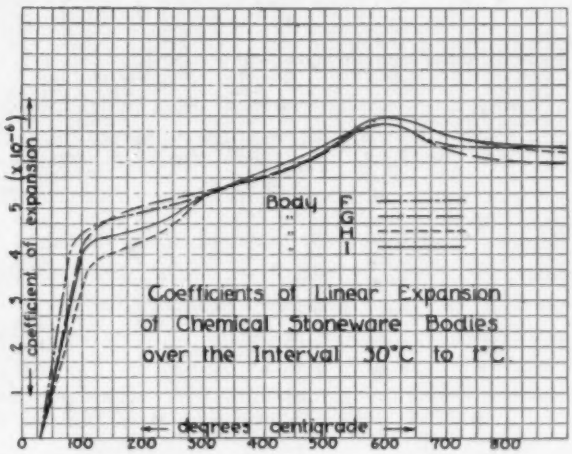

FIG. 5.

If sufficient test-pieces were ordinarily available, it would probably be preferable to take as the impact strength of the specimen that value represented by an impact of such severity as to cause the piece to break at the first blow.

Data Obtained

Table II shows the coefficients of linear expansion of the various bodies, while Figs. 4, 5, and 6 graphically illustrate these values. In general, all of the bodies exhibit considerable irregularity in their expansion over the different temperature intervals, the more porous bodies, *A* and *B*, showing marked nonuniformity. All of the bodies exhibit a rather abrupt increase in the rate of expansion in the neighborhood of 600°C which may be due to the presence of free quartz, the α to β inversion causing the rapid increase in expansion. A logical

explanation for the exceptionally high expansion of bodies *A* and *B* at about 200°C can be made by assuming that part of their silica content has been transformed into cristobalite, the α to β inversion causing the rapid increase in expansion. The expansion phenomena of all of the semivitreous bodies are practically the same in general character and intensity.

TABLE II

COEFFICIENTS OF LINEAR EXPANSION OF CHEMICAL STONEWARE BODIES OVER THE INTERVAL 30 TO *t*°C

Body	114°C	235°C	357°C	483°C	602°C	724°C	844°C
A	7.2	8.1	7.5	7.2	7.6	7.0	6.8
B	6.1	7.4	6.7	6.5	7.1	6.6	6.3
C	4.6	5.3	5.9	6.3	7.1	6.8	6.5
D	4.0	4.4	5.2	5.7	6.4	6.3	6.1
E	4.2	4.4	5.4	5.9	6.8	6.5	6.3
F	4.6	5.0	5.6	6.2	6.9	6.5	6.4
G	4.5	5.2	5.5	6.1	6.8	6.3	6.0
H	3.9	4.5	5.6	6.1	6.8	6.3	6.3
I	4.3	4.7	5.6	6.1	6.9	6.5	6.3

NOTE: Values are to be multiplied by 10^{-6}

TABLE III

PHYSICAL PROPERTIES OF CHEMICAL STONEWARE BODIES

Body	Crushing strength	Impact strength	Heat shock	Modulus of rupture	Modulus of elasticity	Heat-shock number
A	10100	4.18×10^{6}	69.5	2030	11.3×10^{5}	224
B	14400	3.74 "	73.0	1610	11.1 "	202
C	15000	5.16 "	82.2	2210	17.5 "	211
D	25300	4.86 "	82.3	2690	17.1 "	301
E	18200	2.84 "	77.4	1780	15.6 "	221
F	24500	4.74 "	84.2	2780	17.6 "	282
G	21200	4.95 "	72.0	1970	14.9 "	237
H	25500	4.86 "	71.3	2180	16.4 "	237
I	23200	5.07 "	77.3	1900	16.0 "	214

NOTE: Crushing strength, modulus of rupture and modulus of elasticity are expressed as pounds per square inch. Impact strength is expressed as gram centimeters. Heat shock is expressed as per cent.

Table III shows the crushing strength, heat shock, transverse strength, elasticity, and impact strength values for the various bodies. In comparison with its crushing strength, the impact and transverse strength values of body *A* are exceptionally high for some unexplained reason. It should be noted that the elasticity of the porous bodies, *A* and *B*, is distinctly greater (the modulus being smaller) than the more vitreous bodies. Although the relations do not agree perfectly, a body possessing a high transverse strength will, in general, have a high impact and crushing strength.

Many commercial uses of chemical stoneware are such that the ware is often, if not continuously, subjected to sudden temperature changes. Thus, it is often desirable for this type of ware to have a high thermal endurance or ability to withstand sudden and repeated temperature changes. The first essential in this respect is that the

body have a low and uniform rate of expansion, because the lower the expansion the smaller the strains caused by this factor. However, it is possible for one body to be decidedly more resistant to heat shock than another even though its thermal expansion is much greater. This is because the ability to withstand sudden temperature change is dependent upon the thermal diffusivity, elasticity, and mechanical strength of a body as well as upon the thermal expansion. Accordingly, an effort was made to correlate these properties with the heat-shock test.

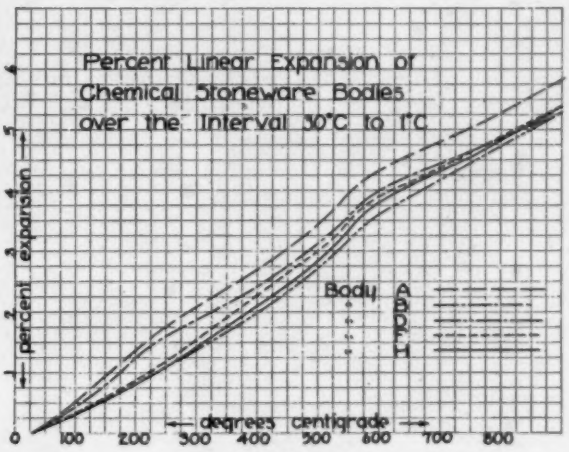

FIG. 6.

Since the thermal diffusivity of the various bodies was not known, it was assumed to be the same in each case. However, due to the great variation in porosity and structure of the various bodies, the thermal diffusivities were, in all probability, quite different. Thus, disregarding the thermal diffusivity, the heat-shock number was calculated as follows:

$$h = \frac{m}{E \times a}$$ in which

h = heat shock number (thermal endurance)
m = transverse strength as modulus of rupture
a = coefficient of linear expansion
E = Young's modulus of elasticity

As determined in this investigation, a low heat-shock value which is desired is indicated by a high heat-shock number. Although the calculated heat-shock numbers do not correlate very accurately with the experimental heat shock values, it is probably because of great differences in thermal diffusivities and the fact that the bodies were so nearly equal with regard to their ability to withstand heat shock. Nevertheless, one would correctly predict from the heat-shock numbers that the various bodies would not be materially different in their ability to withstand heat shock. In this connection it is interesting to note that even though the expansion of body *A* is much greater than that of the other bodies, its ability to withstand heat shock is,

apparently, just as great as that of the other bodies. This is, doubtless, attributable to the fact that body *A* has such a relatively high transverse strength and elasticity.

Summary

It is desirable that chemical stoneware bodies have a high tensile strength and thermal diffusivity and a low thermal expansion and modulus of elasticity. From a purely mechanical standpoint, it is desirable that they have a high impact, transverse, and crushing strength. Of course, the use to which the ware is to be put will largely decide the relative importance of the various physical properties.

The importance of elasticity and mechanical strength as well as thermal expansion is clearly illustrated in the case where a body is subjected to heat shock. It is possible to predict the general resistance of a body to sudden and repeated temperature changes from these physical properties, although a knowledge of the thermal diffusivity greatly increases the accuracy of the prediction.

Conclusions

1. Some of the physical properties which are characteristic of chemical stoneware bodies are given in Tables II and III.

2. The ordinary semivitreous chemical stoneware body expands about .3% when heated over the interval, room temperature to 500°C.

3. The elasticity of highly vitrified bodies is distinctly less than that of more porous bodies.

4. Depending largely upon the composition and degree of vitrification, some physical properties of different chemical stoneware bodies are as follows:

(*a*) Crushing strength varies from 10,000 to 26,000 pounds per square inch.

(*b*) Impact strength varies from 2.8×10^6 to 5.2×10^6 "accumulated" gram centimeters expressed in terms of momentum.

(*c*) Transverse strength is of such an order that the modulus of rupture varies from 1600 to 2800 pounds per square inch for bars broken on a 5-inch span.

(*d*) Young's modulus of elasticity varies from 10×10^5 to 18×10^5 pounds per square inch for bars bent on a 5-inch span.

5. The resistance of chemical stoneware bodies to heat shock is such that they will lose about 75% of their impact strength when subjected to ten alternate heatings and coolings respectively in a furnace at 400°C and water at 30°C.

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ADSORPTION AT CRYSTAL FACES[1]

I. The Growth and Solution of Single Copper Sulphate Crystals in the Presence of Gelatin and Dyes

By T. S. Eckert and W. G. France

ABSTRACT

The growth of crystals and adsorption at crystal faces are important factors in many ceramic processes. In order to understand the mechanism of such growth and adsorption it is necessary to study the growth velocities of single crystals. The present paper concerns itself with the growth and solution of single copper sulphate crystals in the presence of gelatin and dyes.

The formation and growth of crystals is an important factor in many ceramic processes. Likewise the various adsorption phenomena occurring at crystal faces which result in the modification of crystal habit are also of importance. While considerable work has been done on the average crystallization velocities in undercooled melts and supersaturated solutions, there have been but few investigations of the growth velocities of individual crystal faces. Any information obtained concerning growth velocities and adsorption phenomena occurring at crystal faces should therefore be of interest and value in connection with such problems as the fineness of structure in porcelain ware, the mechanism of retardants and accelerators in the setting of cements and plasters, the production of glazes, the crystallization of glass, and many other processes in which the control of crystal growth is required. Due to the lack of satisfactory methods it appears advisable to approach the problem of individual crystal growth velocities by using the relatively simple inorganic compounds first, and deferring the investigation of the more complex silicates until a satisfactory quantitative method has been developed. Therefore, in this preliminary paper, the results obtained in the study of the growth and solution of copper sulphate crystals in the presence of gelatin and dyes are presented.

In a previous article,[2] it was shown that the presence of gelatin in the electrolyte used in the electrochemical precipitation of basic lead carbonate resulted in a marked decrease in the average size of the particles obtained and also in a marked increase in the uniformity of these particles. Subsequent experiments conducted in this laboratory and as yet unpublished show similar effects with other crystalline compounds.

Considering the mechanism of this action the following questions arise: (1) Is the rate of crystal growth uniform or accelerated? (2) Is

[1] Received February 21, 1927.

[2] France and McBurney, *Jour. Amer. Chem. Soc.*, **46**, 540 (1924).

the action of the gelatin preferential for different crystal faces? (3) Does gelatin affect the rate of solution in the same way as it does the rate of growth? In order to answer these questions, it was deemed advisable to study the growth of a substance readily obtainable in large uniform crystals. For this reason, copper sulphate in aqueous solution was selected and in order to procure an exact record during all periods of crystal growth the cinematographic method herein described was devised.

Crystal growth has long been an interesting field for investigation and as far back as 1839 a microscope was used to observe the nature of growing crystalline particles. Much later Richards and Archibald[1] studied the first minute crystals to appear when grown on a microscope slide, such growth being recorded by means of an improvised motion picture camera. Many workers have been interested in studying the velocity of crystallization from aqueous solutions, among whom Marc and Wenk[2] may be cited. Their work indicated that when crystals are introduced into a saturated solution there is an initial and rapid formation of an adsorbed layer of solute molecules. Crystal growth occurs at the expense of molecules in this layer the concentration of which is, however, maintained by further adsorption from the solution.

A number of investigators have studied the growth of individual crystals and it is with such work that this investigation is concerned. Wulff[3] has published an exhaustive treatise on the growth and solution of Mohr's salt. By means of a camera and flashlight apparatus he succeeded in showing the effects of concentration currents upon crystal growth. Andrejew[4] and Leblanc and Schmandt[5] studied the growth and solution of various crystals by observing the changes in weight of the suspended crystals and noted the essential differences between the two processes. Campbell[6] observed the relative rates of growth of potassium alum crystals when suspended in various ways in their saturated solutions. Others have noted the effect upon the crystal habit and the rate of growth produced by foreign substances present in the solution. Marc and Wenk[7] attributed a decreased growth velocity to dye adsorption in the case of some potassium sulphate crystals while Körbs[8] and Ritzel[9] observed variations in the crystal habit of

[1] *Amer. Chem. Jour.*, **26**, 61 (1901).
[2] *Z. Physik. Chem.*, **61**, 385 (1908).
[3] *Z. Krist.*, **34**, 449 (1901).
[4] *Ibid.*, **43**, 39 (1907).
[5] *Z. Physik. Chem.*, **77**, 614 (1911).
[6] *Jour. Chem. Soc.*, **107**, 475 (1915).
[7] *Loc. cit.*
[8] *Z. Krist.*, **43**, 450 (1907).
[9] *Ibid.*, **49**, 152 (1911).

sodium chloride when grown in solutions containing urea and other foreign materials. Reinders[1] observed the formation of dendritic crystals of silver chloride obtained from solutions containing methylene blue and Congo corinth.

More recently crystallization and solution phenomena have been put on a sound theoretical basis by the work of Valeton, Spangenberg, and Niggli. Valeton[2] in his study of alum crystals discussed the geometry of crystal growth and the various concepts involved. Spangenberg[3] has also studied the growth and solution of alum crystals measuring the changes, by means of an ocular micrometer. Niggli[4] in a theoretical paper applied the modern theory of crystal structure to growth and the forms developed.

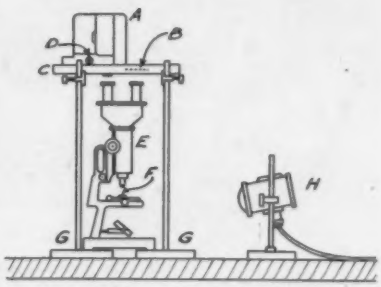

FIG. 1.—Arrangement of apparatus for photographing microscopic crystals. *A*, camera; *B*, ground glass for focusing; *C*, camera holder; *D*, button; *E*, microscope with binocular eyepiece; *F*, glass slide or small dish; *G*, ring stand; *H*, lamp.

It is evident from a consideration of the investigations on crystal growth that more work should be done in order to gain a better understanding of the forces involved at the surface where growth or solution takes place. Since these are essentially kinetic processes it would seem that studies of the rate of growth of individual crystals from pure solutions and also those containing foreign materials might yield valuable data relative to the mechanism of growth and solution phenomena.

Experimental

Copper sulphate crystals of microscopic dimensions were grown on glass slides from one drop of solution. The method of mounting the camera and the arrangement of the apparatus is shown in Fig. 1. The motion picture camera, *A*, is the "Filmo" model manufactured by Bell and Howell, equipped with a spring driven motor and using 16 mm safety positive film. The holder, *C*, contains a piece of ground glass, *B*, which is held in the same horizontal plane that the film in the camera occupies. With a binocular eyepiece fitted to the microscope as indicated it was possible by using matched oculars, to keep the

[1] *Z. Physik. Chem.*, **77**, 677 (1911).
[2] *Z. Krist.*, **59**, 135 and 335 (1924).
[3] *Ibid.*, **59**, 383 (1924) and **61**, 189 (1925).
[4] *Z. anorg. allgem. Chem.*, **110**, 55 (1920).

crystal image in focus at all times. The ring stands, *G*, support the camera holder while the 6-volt lamp, *H*, furnishes the illumination. *D* is a button which when pressed releases the spring-driven motor thus causing the film to be exposed. *F* is a glass slide or small dish holding the growing crystal.

The procedure followed consisted in making a saturated solution of copper sulphate by rapidly stirring a solution containing an excess of small crystals maintained at a temperature of 45°C. With saturation complete the solution was allowed to settle, then by means of an eye-dropper. one drop was placed on a glass slide previously heated to 45°C and immediately placed on the stage of the microscope. A suitable crystal was brought into the field and its growth recorded as described above. Crystals were grown not only in the pure solutions but also in those containing gelatin in various concentrations. All copper sulphate used here and for subsequent experiments was the usual pentahydrate and contained not over .005% iron. Two grades of gelatin were used, one containing 1.24% ash and the other 1.68% ash, and in this article the former gelatin is designated as Gelatin A and the latter as Gelatin B. These two gelatins were used in order to determine what effect, if any, different ash content might have. This was suggested by some unpublished work conducted in this laboratory on the influence of the ash content of gelatin upon the size distribution of particles in the precipitation of silver oxalate and other salts, in which it was found that the ash content appeared to exert an influence upon the effectiveness of gelatin as a protective agent. This naturally suggests that possibly the ash itself and not the gelatin is responsible for the observed effects. However, experiments were conducted in which it was shown that the ash alone was without effect in modifying the crystal habit.

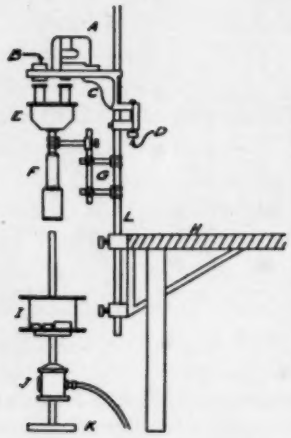

FIG. 2.—Arrangement of apparatus for photographing macroscopic crystals. *A*, camera; *B*, ground glass holder; *C*, camera holder; *D*, focusing screw; *E*, binocular eyepiece; *F*, telephoto lens; *G*, support; *H*, table; *I*, crystallizing chamber; *J*, lamp; *K*, ring stand.

Figure 3 includes some representative crystals photographed by the method described. A few barium nitrate crystals were also grown and photographed but the measurements are not included in the tabulations. All photographs were taken with the camera lens detached using No. 5 oculars and a 16 mm objective. This gave a magnification of about

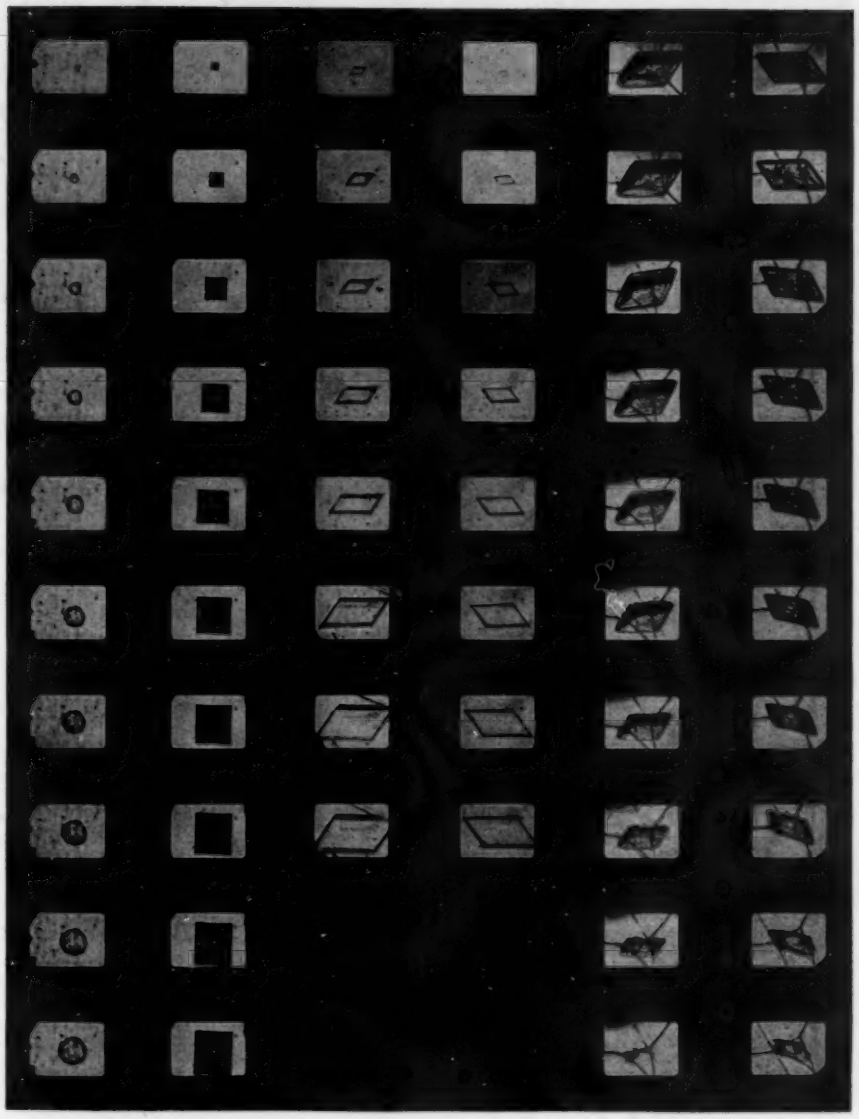

FIG. 3.—Photographs of some representative crystals showing growth and solution. (One minute interval between exposures.) A. Barium nitrate crystal growing in dish (D 22). B. Barium nitrate crystal growing on slide (D 17). C. Copper sulphate crystal growing on slide (E 2). D. Copper sulphate crystal growing on slide. .5% gelatin added (D 9). E. Copper sulphate crystal dissolving in water (E 49). F. Copper sulphate dissolving in 3% gelatin sol (E 80).

15 diameters upon the film. The film was developed to the negative in the laboratory using pyroalkali developer and chrome-alum fixing bath. Special reels were made for conveniently handling the films. Projection for measurement was upon a calibrated screen so placed that a total magnification of 1000 diameters resulted. For this a Bell and Howell Filmo Projector equipped with a condenser which permitted the film to be stopped for any length of time without being damaged by the heat of the lamp, was used. The dimensions of the crystal were obtained from the projected image using a meter stick and from these dimensions the areas were calculated. Since there was no satisfactory method for determining the thickness of the crystal, the areas of the microscopic crystals were confined to the top and bottom surfaces which were assumed to be identical. Table I contains the average values for all crystals grown in this manner while Table II shows some representative data from which these averages were obtained. Figures 4 and 5 include curves which show the effectiveness of gelatin in retarding the rate of crystal growth.

TABLE I

AVERAGE VALUES FOR RATES OF GROWTH OF MICROSCOPIC COPPER SULPHATE CRYSTALS (GROWN ON GLASS SLIDE)

Number of crystals	Concentration of solution (per cent)	Increase in area top and bottom surfaces (cm^2 per minute)
27	No Gelatin	.000660
6	.1 Gelatin A	.000455
6	.3 " "	.000336
5	.5 " "	.000285
11	.7 " "	.000279
9	.3 Gelatin B	.000368
9	.5 " "	.000311
6	.8 " "	.000223
6	1.0 " "	.000229

The rates of growth of some larger crystals were also investigated using the apparatus shown in Fig. 2. Photographs of this apparatus and also that described in connection with Fig. 1 are included in a previous article by France.[1] Figure 2 shows a camera holder possessing great rigidity and fitted with a micrometer adjustment for vertical motion. *A* is the camera supported by the holder, *C*, and *B* is a ground glass holder adjusted so as to occupy the same plane as the film. *D* is a focusing screw which raises or lowers the holder very small distances. Rod *L* is rigid and allows *C* to be moved up or down and clamped in any desired position. The binocular eyepiece *E*, and telephoto lens, *F*, provide an optical system for focusing the image upon the film. The crystallizing chamber, *I*, consists of a glass cylinder ground so that it is air-tight when covered with two glass plates. *J* is a 6-volt lamp supported by the ring stand, *K*.

[1] France, Colloid Symposium Monograph, Vol. 3, Chap. 22, The Chemical Catalog Co., Inc. (1925).

TABLE II

SOME REPRESENTATIVE DATA FOR RATES OF GROWTH OF MICROSCOPIC COPPER SULPHATE CRYSTALS GROWN IN SATURATED SOLUTIONS CONTAINING GELATIN

Crystal number	Per cent gelatin and kind	Dimensions at beginning (cm×1000)	Dimensions at end (cm×1000)	Area at beginning ($cm^2 \times 10^6$)	Area at end ($cm^2 \times 10^6$)	Increase in area ($cm^2 \times 10^6$)	Time in minutes	Increase in area (cm^2 per minute)
B14	0.0	15×22	39×50	660	3900	3240	5	.000648
B19	0.0	9×10	34×53	180	3604	3424	5	.000685
E 5	0.0	7× 9	34×48	126	3264	3138	5	.000628
G15(b)	.3A	10×11	25×38	220	1900	1680	5	.000336
G18	.3A	9×12	24×44	216	2112	1896	5	.000379
G45	.5B	7×10	24×34	140	1632	1492	5	.000298
G51(b)	.5B	9×12	25×37	216	1850	1634	5	.000327

Crystal growth was studied by growing small seed crystals in saturated copper sulphate solutions using concentrated sulphuric acid as the desiccating agent. Five small crystallizing dishes of uniform size together with a large dish holding a definite quantity of sulphuric acid were placed symmetrically in the crystallizing chamber. Small seed crystals previously weighed were placed in each of the five dishes which contained 1 cc of a copper sulphate solution saturated at 25°C. Each crystal was photographed, the cover placed upon the chamber and growth allowed to take place for a period of twelve hours. At the end of this time-interval the crystals were photographed again, removed from the dishes, dried, and weighed. Crystal areas at the beginning and end of the growth period were obtained by measuring the projected image upon the calibrated screen as previously described. The total surface area of each crystal, which was used in these calculations, was determined by using the average crystal thickness, which was calculated from the density and the area of the image, assuming the crystal to be a rhombic parallelopiped. By this method the total area of each crystal was determined both at the beginning and end of the growth period. The gain in total area divided by the time gave a measure of the rate of growth. Besides Gelatins A and B the effect of the following six dyes upon the rate of growth was observed: namely, quinoline yellow, naphthol yellow, ponceau 2R, methyl violet, bismarck brown, and methylene blue, all of which were used in concentrations of 0.1%. All solutions were made as previously described. Table III contains the tabulated results obtained while Fig. 6 shows graphically the effect of gelatin upon the growth. Since viscosity plays an important part in crystal growth it was determined for each solution using a standard Ostwald viscosimeter. These results are indicated in Fig. 7. All measurements were made as soon as the solutions were prepared and filtered.

A series of experiments was also carried out in order to determine the rate of solution of some large copper sulphate crystals whose length varied between 5 and 10 mm. The apparatus shown in Fig. 2 was

used with the exception that a small dish about 8 cm in diameter replaced the crystallizing chamber at *I*. Solvent action at all surfaces was provided for by placing the crystal on a small platinum tripod in the bottom of the dish. The crystal properly placed was photographed and 50 cc of water or solution at 27°C added and the time for complete disappearance of the solid noted. Exposures were made at one minute intervals but in the calculations only the initial area was used. Rates of solution were determined using water sols of Gelatins A and B and 0.1% solutions of the dyes previously mentioned. The total areas of the crystals were determined as previously described. These areas divided by the time gave the rates as indicated in Table IV. Figure 8 shows the effect of the two grades of gelatin upon the rate of solution. Some representative crystals photographed during the solution process are shown in Fig. 3.

Discussion

An examination of the curves in Fig. 4 makes it evident that increasing concentrations of both Gelatins A and B definitely decrease the rate of growth in the case of microscopic crystals, Gelatin A apparently having a greater retarding influence than Gelatin B. Probably the effect observed may be due to a number of factors rather than to any single one. Both curves show a maximum retarding concentration of the added material. Such a tendency would seem to indicate that possibly adsorption of the foreign material might play some part in decreasing the rate of growth. In making the solutions it was noted that the gelatin showed a slight tendency to be salted out when present in concentrations greater than 0.5%. This might partially account for the flat portion of the curve, yet it is to be noted that adsorption of the added material is the most plausible explanation to account for the changed ratios of growth velocity referred to later and indicated in Table V. The curves in Fig. 5 show the growth of individual microscopic crystals, time being plotted against average diameter, the latter value being the average of length and width at the time stated. Curves of crystals grown in the absence of gelatin have greater slopes than those in its presence, indicating the retarding influence of the gelatin.

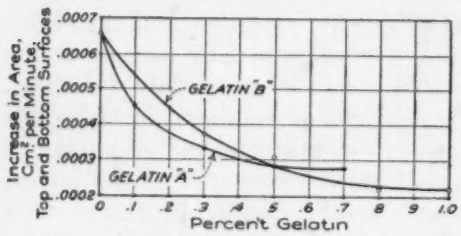

FIG. 4.—Curves indicating rates of growth of microscopic copper sulphate crystals in solutions containing gelatin. (Saturation temperature, 45°C.)

Since the curves in each case approximate straight lines it is evident that the drops of solution in which the crystals grew were saturated at all times, thus rendering untenable any explanation accounting for decreased rate of growth on the basis of a marked change in concentration of the solution.

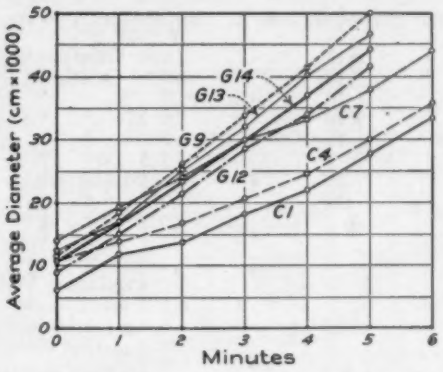

FIG. 5.—Curves indicating rate of growth of some individual copper sulphate crystals grown on slides. No gelatin added to G 9, 12, 13, and 14. .1% Gelatin A added to C 1, 4, and 7.

The curves in Fig. 6 show the effect of gelatin upon the growth of macroscopic crystals. As in the case of the microscopic crystals Gelatin A is more effective in retarding growth than Gelatin B. During the course of these experiments the room temperature varied slightly, the general effect being that the higher the temperature the more rapid was the growth. Table V contains average values showing the change in ratios of increase in length to width for some macroscopic crystals. Being ratios of growth increase they indicate that the rate of growth along the crystal axes varies at a nonuniform rate for different concentrations of gelatin. This would apparently indicate that the gelatin was probably adsorbed to different degrees at the different crystal faces, thus changing the crystal habit by inhibiting growth due to the difficulty with which the ions penetrated the adsorbed layer or layers.

Markedly different effects upon crystal growth were obtained with the dyes. All concentrations were 0.1% and due to color changes satisfactory photographs were not obtained in each case; however, the weights afford a comparative measure of the growth rates. Quinoline yellow, the first dye used, made the crystals greenish in color, much elongated and slightly thicker than a normal crystal. Inspection of Table III shows that while the rate of growth by area was much increased by this dye, the growth by weight was somewhat reduced. Ponceau 2R, naphthol yellow, and methyl violet were found to be without apparent effect upon the shape or form of the crystals obtained. Bismarck brown made the crystals elongated and very thin with slight closely packed laminations, weight and area data showing a marked decrease. Methylene blue produced crystals of the usual shape, slightly elongated but extremely thin and while possessing a large area the rate of growth by weight was very small.

TABLE III

AVERAGE VALUES FOR RATES OF GROWTH OF MACROSCOPIC COPPER SULPHATE CRYSTALS. GROWN IN CRYSTALLIZING CHAMBER
(Temperature 25–27°C)

Number of crystals	Concentration of solution (per cent)	Increase in area (cm² per hour)	Increase in weight (gms per hour)
10	0.0 Gelatin	.105	.0098
10	0.05 Gelatin A	.101	.0089
10	0.1 " "	.084	.0076
10	0.26 " "	.092	.0081
10	0.3 " "	.089	.0070
5	0.5 " "	.029	.0034
20	0.1 Gelatin B	.110	.0094
20	0.3 " "	.102	.0096
5	0.5 " "	.080	.0078
5	0.7 " "	.024	.0029
5	1.0 " "	.001	—
5	0.1 quinoline yellow	.165	.0091
5	0.1 ponceau 2R	.105	.0105
5	0.1 naphthol yellow	.095	.0100
5	0.1 methyl violet	.108	.0097
5	0.1 bismarck brown	.089	.0063
10	0.1 methylene blue	.129	.0065

TABLE IV

AVERAGE VALUES FOR RATES OF SOLUTION OF MACROSCOPIC COPPER SULPHATE CRYSTALS

Number of crystals	Solvent concentration (per cent)	Decrease in area (cm² per minute)	Decrease in weight (Grams per minute)
26	Water at 27°C	.136	.0092
6	0.1 Gelatin A	.130	.0096
11	0.3 " "	.133	.0087
6	0.5 " "	.129	.0083
5	0.6 " "	.128	.0087
12	1.0 " "	.115	.0076
8	2.0 " "	.092	.0059
6	3.0 " "	.078	.0046
2	0.1 Gelatin B	.157	.0100
3	0.5 " "	.132	.0085
3	0.7 " "	.124	.0087
3	1.0 " "	.118	.0076
4	2.0 " "	.098	.0059
4	3.0 " "	.073	.0046
16	0.1 all dyes	.134	.0093

TABLE V

AVERAGE VALUES FOR RATIOS OF INCREASE IN LENGTH TO WIDTH FOR MACROSCOPIC COPPER SULPHATE CRYSTALS
(Saturation Temperature 25°C)

Number of crystals	Concentration of Gelatin A in solution (per cent)	Increase length and increase width
10	0.0	1.66
10	.1	1.34
10	.24	1.25
10	.35	1.25
10	.5	0.95
Room temperature for crystals above (28–30°C)		
Room temperature for crystals below (25–27°C)		
10	0.0	1.40
10	0.1	1.44
10	0.26	1.23
10	0.3	1.23
5	0.5	0.72

The effect of gelatin upon the rate of solution is indicated in Fig. 8. As shown in Table IV the dyes were without effect upon the rate of solution. The two grades of gelatin apparently showed no decided variations in their ability to reduce the rate of solution and this is what might be expected since the viscosity curves for these sols were almost identical. The straight line relationship of solution rates and concentration of gelatin would seem to indicate that diffusion as affected by the viscosity of the solutions was the limiting factor in this case. Some data not included here showed that each of the six dyes at the concentrations used had no effect upon the viscosity of water, whereas gelatin solutions showed increased viscosities in proportion to the concentration of the added material.

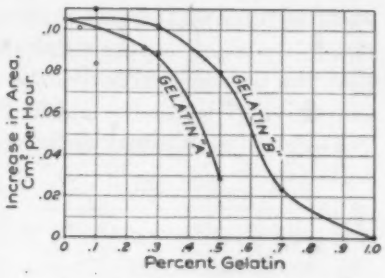

FIG. 6.—Curves indicating rates of growth of macroscopic copper sulphate crystals in solutions containing gelatin.

The space lattice structure of crystals as developed by X-ray analysis has given an added interest to the problems of crystal growth. Niggli, Valeton, and others[1] have represented the outer zone of a crystal as unsaturated with respect to valence or force fields. The crystal face attempts, therefore, in a suitable environment to reach an equilibrium by the addition of new particles. Neutralization of forces is, however, not attained for a new surface forms and growth continues. Crystals can therefore be considered as the stable form resulting from the attractive and repulsive anisotropic forces existing in the medium from which growth takes place.

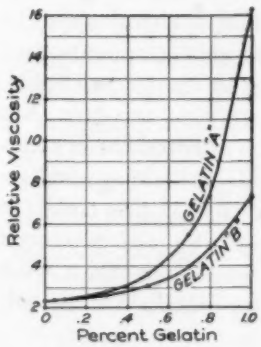

FIG. 7.—Curves indicating relative viscosity of copper sulphate solutions containing gelatin. (Temp. 27°C)

That crystals are the result of a complicated chemical field existing between the crystal and its environment is evident from the fact that slight amounts of foreign materials in the solution change the shape and form of the crystal remarkably. The effect of urea upon sodium chloride has already been mentioned and of no less importance is the effect of gelatin and the dyes mentioned, upon the crystal habit of copper sulphate.

According to the molecular orientation theory of adsorption as developed by Langmuir and by Harkins various degrees of adsorption

[1] *Loc. cit.*

may take place depending upon the nature of the adsorbed material, adsorbing surfaces, and environmental conditions. The results herein presented appear to be in harmony with this theory.

Gelatin, though of unknown structure, is made up of a large number of amino-acid molecules possessing polar groups, which might reasonably be expected to render it capable of being readily adsorbed by surfaces offering the necessary attractive fields. Furthermore since the crystal faces of copper sulphate are not all alike, it is quite possible that the degree of adsorption varies with the type of face, such variations giving rise to the marked changes in crystal habit observed.

The results obtained with the dyes clearly show the effect of a change in the nature of the adsorbed material, in modifying crystal habit. As three of the dyes were without effect on the growing crystals, and since they all possessed polar groups, it would seem that the molecular structure was not conducive to the formation of an adsorption layer in each case. It is also probable that differences in the state of dispersion of the dyes may be responsible for these variations. Taylor[1] classifies bismarck brown and methylene blue in water as crystalloid, methyl violet as semicolloid, and naphthol yellow as colloid. From this it appears that molecularly dispersed dyes exert the greatest effect on the crystal habit. However due to incomplete information and in view of the fact that Kohlschütter and Egg[2] found that those dyes which affected the crystallization of calcium carbonate were apparently colloidally dispersed no definite conclusion seems warranted in this connection at this time. It should be noted that those dyes affecting crystal growth, also produced decided color changes in the growing crystal, and since they were without effect on the viscosity of water, the importance of the adsorption layer is further emphasized.

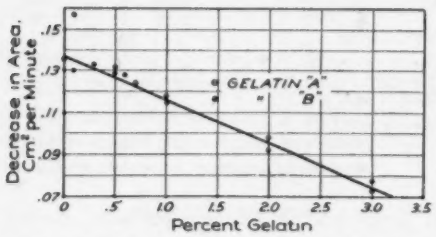

FIG. 8.—Curve showing effect of gelatin upon the rate of solution of copper sulphate crystals. (Temp. 27°C)

In stressing adsorption, the effects of changing viscosities on crystal growth, must not be underestimated, yet in view of the data presented it is unlikely that viscosity effects exert as great influence on the crystal growth as does adsorption. However, in the process of solution viscosity and convection currents produced by the rapidly changing concen-

[1] W. W. Taylor, The Chemistry of Colloids, p. 274, 2nd. edition (1921) Longmans, Green and Co.

[2] *Helvetica Chim. Acta*, **8**, 697–703 (1925).

tration of solution adjacent to the crystal faces, are seemingly of greatest importance in determining the rates with which the crystals dissolve.

Inability to control such factors as uniformity of supersaturation, number of nuclei present, rate of evaporation and rate of cooling are no doubt responsible for some of the variations observed in this work. These and other factors such as the influence of colloidally and molecularly dispersed dyes on the rates of growth of crystals of definitely known structure are now under investigation.

Summary

1. A method employing a cinematographic camera, of small size, for the study of growth and solution of individual microscopic and macroscopic crystals is described.

2. Gelatin decreases the rate of growth of copper sulphate crystals and at the same time changes the growth velocity at a nonuniform rate in different directions. Variations in the effect of the ash content of gelatin are noted.

3. The dyes, quinoline yellow, bismarck brown, and methylene blue, greatly change the crystal habit and decrease the rate of growth of copper sulphate crystals. Naphthol yellow, ponceau 2R, and methyl violet are without such an effect.

4. The rates of solution of copper sulphate crystals in gelatin and dye solutions have been determined. Apparently viscosity and convection currents are the important factors in determining the solution rates.

5. The effect of an adsorbed layer upon crystal growth is noted and its importance in the observed results is discussed. Specific adsorption is believed largely responsible for the changes in crystal form produced by gelatin and the dyes mentioned.

Acknowledgment The authors wish to extend thanks to Julius F. Stone, for providing the motion picture camera and projector, and to F. H. Haskett, University photographer, for the use of the telephoto lens.

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HYDROGEN-ION CONCENTRATION AND ELECTRICAL CONDUCTIVITY OF CLAY SLIPS[1]

Part II. Laboratory Study

By A. H. Fessler and Hobart M. Kraner

ABSTRACT

This paper supplements a previous paper on this subject. The authors have tried to determine in the laboratory the extent of variations on hydrogen-ion concentration, electrical conductivity, and viscosity caused by those variable conditions which might exist in factory operation such as temperature, vigor and time of stirring, salts, etc.

It appears that the viscosity of the slip remains to be the most indicative of its workability whereas its electrical conductivity shows some promise of being used as an additional method of control. Little promise was found for H-ion concentration determinations.

Note: It should be remembered that the term p_H represents the logarithm of the reciprocal of the H-ion concentration or $p_H = \log\left(\frac{1}{CH}\right)$. This is a logarithmic value. Therefore a solution having a p_H value of 6.0 contains ten times as many H ions as one having a p_H value of 7.0. Also if the p_H increases in value the H-ion concentrations decreases.

Introduction

The apparatus and method of determining the H-ion concentration, conductivity and viscosity of slips were described in a previous paper.[2]

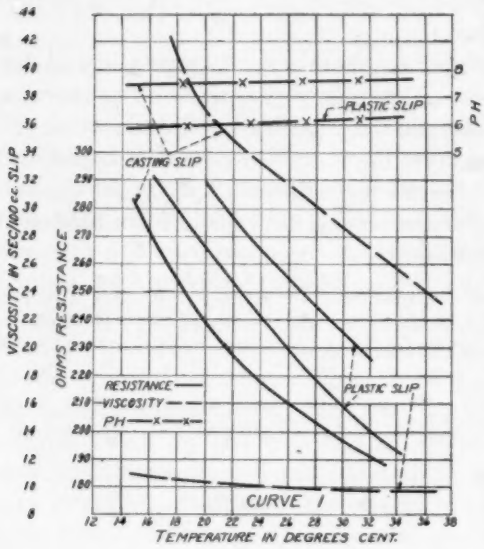

Fig. 1.

In this paper we have limited the work to the laboratory and endeavored to find the cause of the variations occurring in our data on plant slip control. The conductivity indicates that more variations probably occur in the slips than are indicated by the H-ion concentration or viscosity. It is for this reason that the work was carried on in the laboratory where the conditions were maintained constant.

The Effect of Temperature

The temperature of the slips as found in the plant varies slightly, but probably enough to cause some difference in slip conditions.

[1] Received May 12, 1927.

[2] *Jour. Amer. Ceram. Soc.*, **10**]7], 501–507 (1927).

(See Fig. 1.) It was therefore necessary to determine in the laboratory what effect this variation had on the measurements.

This data was obtained by cooling a given sample of slip to 18°C and measuring the change taking place while heating up to 38°C. The slip sample was immersed in a water bath and slowly stirred until the desired temperature was obtained. The curves given for conductivity[1] are similar to curves found for water with change in temperature.

The curve given for viscosity with change in temperature indicates the importance of standard temperature when using viscosity measurements as a method of slip control. Therefore, in all the data reported in this paper they are corrected for temperature changes or the temperature was held constant.

Effect of Stirring

It was observed in the laboratory that by additional stirring of the casting slip sample obtained from the plant, its viscosity could be considerably lowered. The effect of stirring on the H-ion concentration, conductivity, and viscosity of casting and plastic slips was therefore studied. (See Fig. 2.)

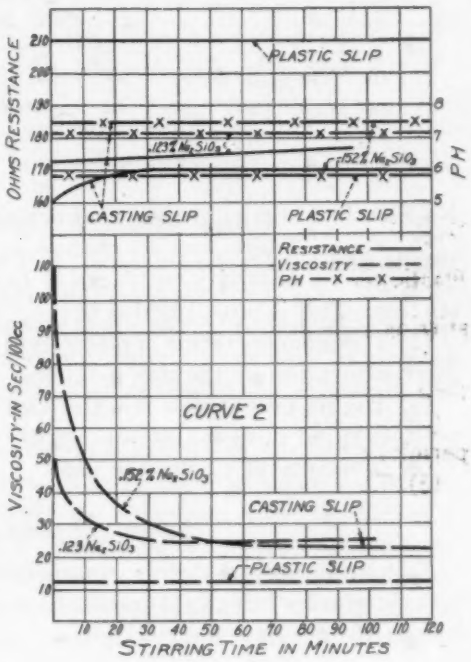

FIG. 2.

Casting Slip Two samples were used: one containing .123% and the other .152% of Na_2SiO_3. The samples were vigorously stirred in a beaker with a small glass stirring paddle, rotating at 1750 r.p.m.

The conductivity of the slip which contained .123% electrolyte gradually decreased with vigorous stirring but the slip containing .152% electrolyte decreased rapidly in the first twenty minutes but from then on showed no change.

In the slip containing .152% electrolyte the viscosity was lowered rapidly for the first 55 minutes of stirring and then continued to

[1] F. H. Getman, Outlines of Theoretical Chemistry, p. 414.

decrease, but more slowly. The viscosity of the other sample decreased rapidly for forty minutes and then remained constant with continued stirring. This shows that the effect of stirring on various slips varies with their electrolyte contents and indicates the importance of standardizing casting slip adjustment procedure.

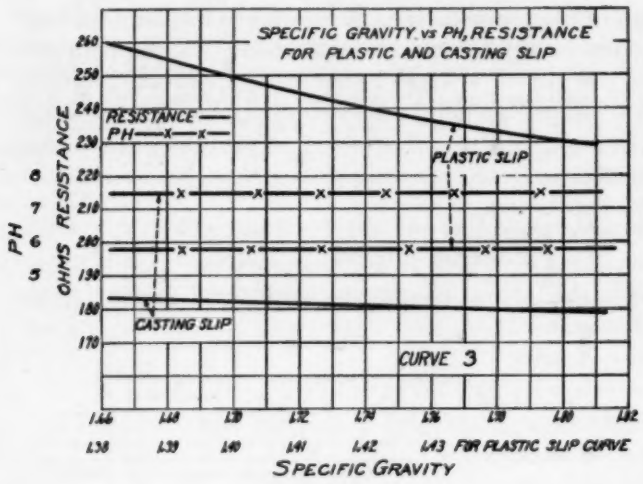

FIG. 3.

The H-ion concentration was not changed with stirring and since additional stirring probably makes the electrolyte present more effective it would seem that the H-ion concentration is not influenced as much by Na_2SiO_3 in a slip as are the conductivity and viscosity values.

Plastic Slip There was no change in the H-ion concentration, conductivity or viscosity in the plastic slip with additional stirring. This is probably due to:

(1) Low concentration of electrolyte which permits more nearly complete adsorption by the clay particles.

(2) Higher percentage of water and consequent low viscosity which permits rapid diffusion of the electrolyte.

(3) The type of electrolyte used.

Effect of Specific Gravity

Figure 3 indicates that conductivity increases with increase of specific gravity but the H-ion concentration is not appreciably affected by specific gravity changes.

Effect of NaCl

The addition of NaCl to the plastic slip does not change the H-ion concentration of the slip. (See Fig. 4.) With an increase in NaCl the conductivity and viscosity increase. There is a very marked relation

between the conductivity and viscosity in this experiment and therefore conductivity shows a possibility for plastic slip control.

It should be noted that an increase in conductivity does not necessarily indicate any change in H-ion concentration, since conductivity is, other things being equal, a measure of the total concentration of ions, while the H-ion determination is a measure of the concentration of hydrogen ions. It is possible for an increase in conductivity to be associated with an increase of H-ion concentration, as in the case of addition of $AlCl_3$; a decrease, as in the case where Na_2SiO_3 is added; or no change where a neutral salt, such as NaCl, is added.

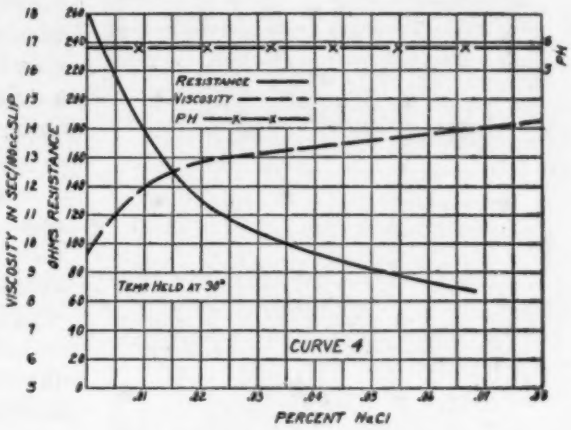

FIG. 4.

Effect of Na_2SiO_3 on Casting Slip

The slip sample represented in Fig. 5 was taken from the ball mill of factory before its viscosity had been adjusted with Na_2SiO_3. The slip was then diluted by adding tap water in the same proportion as it was added to the ball mill. This gave a slip correct in density but low in Na_2SiO_3 content. The Na_2SiO_3 was then added to the sample in the proportions shown on Fig. 5.

The H-ion concentration values decrease and the conductivity values increase as straight line functions with an increase in Na_2SiO_3 whereas the viscosity responds as usual; it first decreases until it reaches a minimum and then increases with increase in electrolyte. H-ion concentration and conductivity seem to bear no relation to the viscosity variations of a slip affected by Na_2SiO_3 variation. The viscosity is affected more by Na_2SiO_3 than are conductivity and H-ion concentration values.

Effect of $AlCl_3$ and $MgSO_4$

The viscosity, conductivity, and H-ion concentration increase with an increase in the concentration of the electrolyte. (See Figs. 6 and 7.) This increase should be expected since both of these are acid salts.

Summary

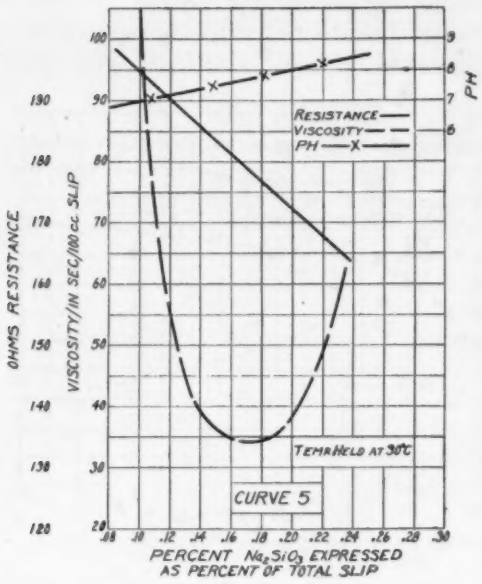

FIG. 5.

1. The viscosity values decrease with increase in temperature and this is more notable with casting slip than with plastic slip. This variation is sufficient to warrant consideration where the viscosity measurements are used in plant slip control.

2. The H-ion concentration decreases and the conductivity measurements increase with increase in temperature.

3. Vigorous stirring affects the viscosity and conductivity values on casting slips which indicates the importance of either providing stirring to equilibrium or standardization of the stirring time. The plastic slip is not affected appreciably by additional stirring.

4. Within the limits studied, the conductivity is increased with increase of specific gravity. The H-ion concentration is not changed appreciably.

5. NaCl added to the slip does not affect its H-ion concentration. The viscosity and conductivity are increased by increase in NaCl. The behavior of the H-ion determinations in this case eliminates this method of slip control if NaCl is added to the slip to increase plasticity.

6. Na_2SiO_3 added to a slip decreases the H-ion concentration because Na_2SiO_3 gives a basic reaction. The viscosity follows the usual behavior of a slip with increase in Na_2SiO_3 and the conductivity increases.

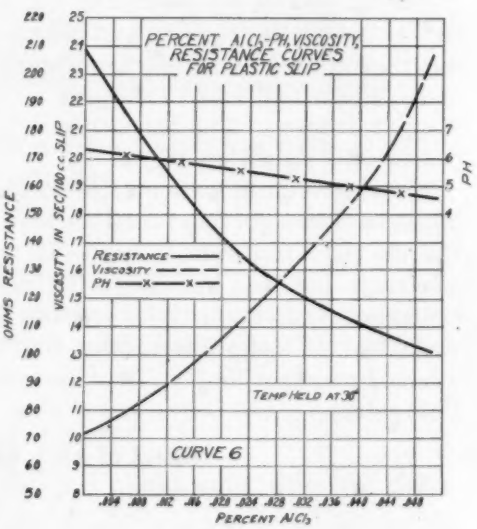

FIG. 6.

7. The addition of $MgSO_4$ and $AlCl_3$ to slips shows that there is a difference in effect by adding a slightly acid salt such as $MgSO_4$ and a stronger acid salt such as $AlCl_3$. The H-ion concentration viscosity and conductivity values are increased.

The preceding data may be summarized as follows:

NaCl additions (stirring and temperature constant): (*a*) do not affect H-ion concentration, (*b*) increase conductivity, and (*c*) increase viscosity.

Na_2SiO_3 additions (stirring and temperature constant): (*a*) decrease H-ion concentration, (*b*) increase conductivity, and (*c*) affect viscosity values in the usual manner.

$MgSO_4$ and $AlCl_3$ additions (stirring and temperature constant): (*a*) increase H-ion concentration, (*b*) increase the conductivity, and (*c*) increase the viscosity.

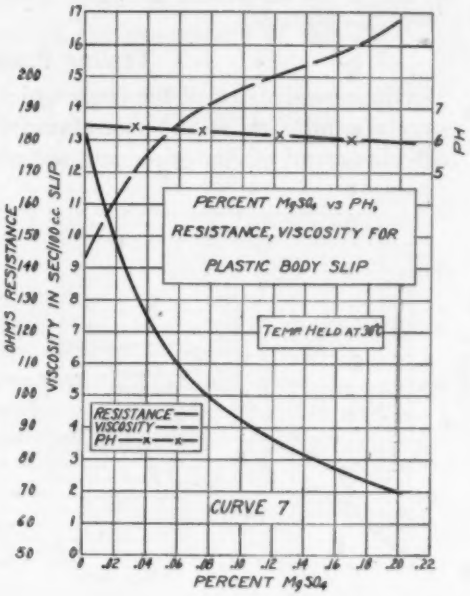

FIG. 7.

Conclusions

The results indicate what variations occur to influence the values obtained.

Conductivity might well be used as a means of plant slip control if all the important conditions can be maintained fairly uniform. The method indicates wide variations that are not evident in the workability of the bodies made from the slips.

H-ion concentration measurement does not seem to offer itself as a means of plant slip control. It is troublesome to keep electrodes in a working condition and as the clay gathers on the cell, the readings become erratic and of doubtful accuracy.

The viscosity is perhaps the best method of control as it more nearly indicates the working properties of the slips and resulting bodies.

WESTINGHOUSE ELECTRIC & MFG CO.
EAST PITTSBURGH, PA.

AN INVESTIGATION OF SOME BALL AND CHINA CLAYS.[1]

By C. W. Parmelee and T. N. McVay

ABSTRACT

A report on the investigation of the properties of thirteen ball clays and seven true and sedimentary kaolins such as are used in the manufacture of electrical porcelain for high tension insulators.

Testing Procedure

In an investigation of the clays which are being used by the electrical porcelain industry in the manufacture of high tension ware, thirteen ball clays and seven true and sedimentary kaolins were examined. The results are described in the following pages.

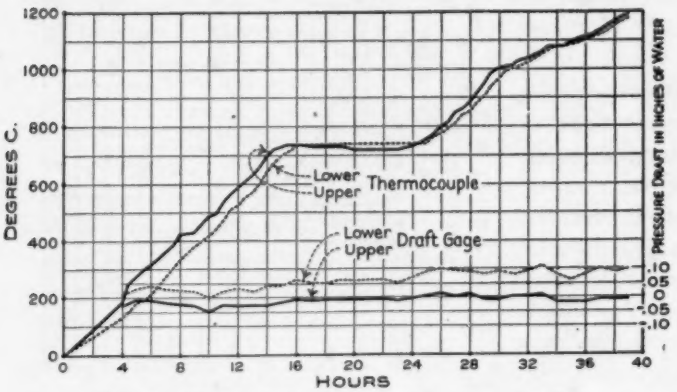

FIG. 1.—Firing of clay test pieces in oil-fired kiln No. 3 (cone 6), June 11–12, 1925.

The investigation included determinations of conduct during deflocculation, amount of water of plasticity, the amount and the character of the residue on a 120-mesh sieve, the amount of adsorption of malachite green, the transverse strength of the washed clay mixed with an equal weight of potters' flint, the rate of oxidation, the firing behavior, and the color of the fired clays. The following methods were employed in making these tests.

1. Deflocculation Test

After air drying, the clays were crushed to pass through a 10-mesh sieve. Thirty grams of each clay were weighed into pint jars and enough water and electrolyte added to make a total volume of 300 cc. The percentages of electrolyte varied from 0.1 to 0.5% of the weight of the clay. These jars were rotated in a revolving shaker for four hours, after which 100 cc samples were measured into graduated cylinders. After ten days the height of the sediment and the height of the clay in suspension were measured.

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[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., Feb. 1927. (White Wares Division.) Received October 11, 1926.

2. Water of Plasticity The crude clays were crushed to pass 10-mesh, and then tempered with water and thoroughly wedged by hand, after which they were stored in a damp jar for twenty-four hours. Test pieces 3 x 1 x 1 inch were made in brass molds, weighed, allowed to air dry, and then dried at 110°C. The water of plasticity was calculated in terms of the percentage of the dry clay according to the usual formula.

The washed clays were allowed to dry in cloth-lined plaster bats to the proper working consistency and the same procedure was followed as stated above.

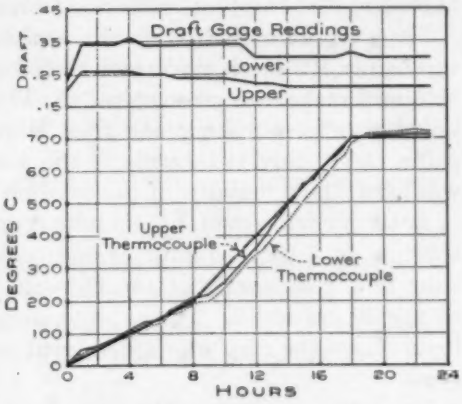

FIG. 2.—Oxidation firing. Time-temperature curve, Nov. 18, 1925.

3. Volume Drying Shrinkage The wet pieces were weighed and their volumes determined in an over-flow volumeter. The specific gravities were then calculated in order to learn if the results were consistent. After drying, the pieces were soaked in water-free kerosene for twenty-four hours and their volumes determined in kerosene by the suspended weight method. Specific gravities of the test pieces were calculated occasionally as checks on the volume determinations.

4. Determination of Clay Volumes Thirty bars for each clay were made for firing. The volumes of five of the newly-made bars were determined in either an over-flow volumeter or in a Schurecht pycnometer. These bars were then dried, weighed, and the volumes of ten determined by the suspended weight method. The specific gravities of these ten were calculated and from this data the volumes of the other twenty test pieces calculated. In using this method the specific gravities should check in the second decimal place. The necessary precautions are that all pieces must be made from a roll of clay with a uniform water content, and that all thirty bars must be dried under identical conditions.

5. Test for Residue on 120-Mesh Twenty-five grams of each clay were placed in a quart jar with 250 cubic centimeters of water, the amount of electrolyte which would cause maximum deflocculation and also a number of small cubes of rubber. The jar was agitated in a revolving shaker for six hours after which the slip was passed through a 120-mesh sieve and the residue

was carefully washed with water, dried, weighed, and examined with a binocular microscope. The residue particles were practically free from adhering clay. The purpose of this test was to obtain an idea of the fineness of these clays according to Ashley's method.

6. The Malachite Green Adsorption Test

A standard solution containing 3 grams of malachite green dissolved in 1000 cc of pure distilled water was used. Pure distilled water is necessary since impurities present may decompose the dyestuff.

Fifteen grams of each of the washed ball clays were dried, passed through a 100-mesh sieve and placed in a pint jar with 300 cc of the standard malachite green solution. The jars were agitated in a revolving shaker for one hour and then allowed to stand over night. With china clays, only two-thirds of the above amount of malachite green was used, the remainder of the solution being water.

A secondary standard solution containing 25 cc of the original solution in a total volume of 500 cc was used for comparison in one tube of a colorimeter of the Ostwald-Schreiner type which was filled to the 20 cm mark. To the other tube, enough supernatant solution from above the clay was added until the colors in both tubes were the same.

From the above described determinations, the weight of malachite green adsorbed by one gram of clay was calculated.

7. Transverse Strength Tests

The crude ball clays were air dried, screened to pass through a 10-mesh sieve, mixed with an equal weight of potters' flint and blunged mechanically with water until the mixture was homogeneous. The slip so obtained was passed through a 120-mesh sieve and allowed to dry to the proper working consistency in cloth-lined plaster bats. The body was then thoroughly wedged into the form of a cube and allowed to stand in a damp jar for at least 24 hours to secure a uniform distribution of the water. After this, pieces of clay a little larger than the briquette desired were cut from the cube of clay and tightly wedged into the mold. The bars when wet measured 7 x 1 x 1 inch. These were then dried according to the Standard Methods of the AMERICAN CERAMIC SOCIETY.

A transverse strength testing machine which applied the load at a constant rate of 100 lbs. per minute was used for breaking the pieces. Fifteen bars of each clay were tested and the moduli of rupture calculated by the usual formula.

The china clay test pieces were made from a mixture of 80% china clay and 20% Tenn. ball clay No. 5. The remainder of the procedure was the same as that given for the ball clays.

8. Firing Behavior

Standard size test pieces were molded, dried, and after their dry volumes were determined

as noted under (3) they were fired in an oil-fired test kiln. Separate firings were made at cones 03, 01, 2, 4, 6, 7, 8, 10, 12, and 14. A typical firing curve is shown in Fig. 1. Two thermocouples were used, one being placed in the top and one in the bottom of the kiln. The distance between the hot junctions of the couples was about 30 inches. From time to time the couples were compared with a standardized couple. Draft measurements were taken and gas analyses were made at two-hour intervals at temperatures above 750°C in order to attain as nearly as possible identical conditions for the different firings. The fired pieces were weighed dry, and after saturation by boiling under a vacuum at room temperature for four hours, they were weighed in air and suspended in water. The porosities according to Purdy's formula were $\frac{W-D}{W-A}$ 100 for open pores and $1-\frac{\text{bulk sp. gr.}}{\text{true sp. gr.}}$ for total pores. The volume shrinkages were calculated in terms of the volumes of the pieces before firing. In addition the apparent, bulk, and true specific gravities were determined for the test pieces fired at cones 03, 2, 6, 10, 12 and 14. From the data obtained the volumes of the closed pores in terms of the apparent volume and also the total porosities were calculated.

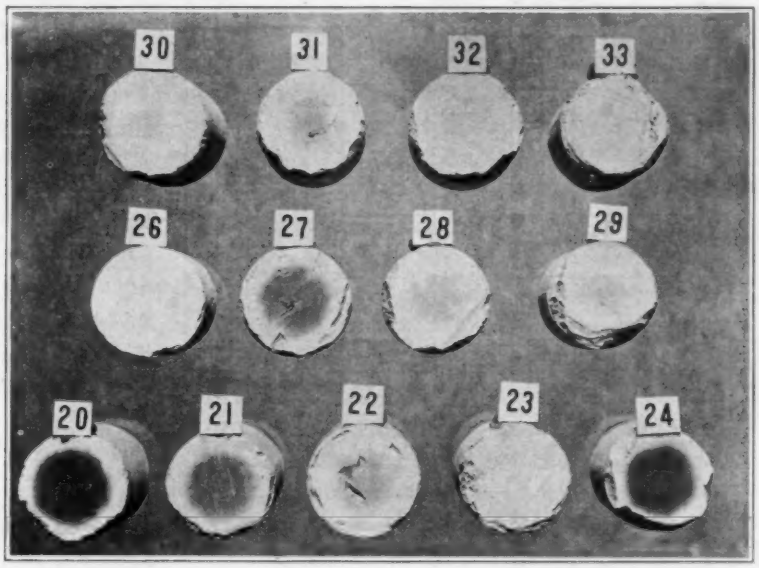

FIG. 3.

9. Oxidation Behavior

Cylinders $1\frac{3}{4}$ inches in diameter and 4 inches long were squeezed out of a piston press and after drying were placed in the kiln so that there was a uniform distribu-

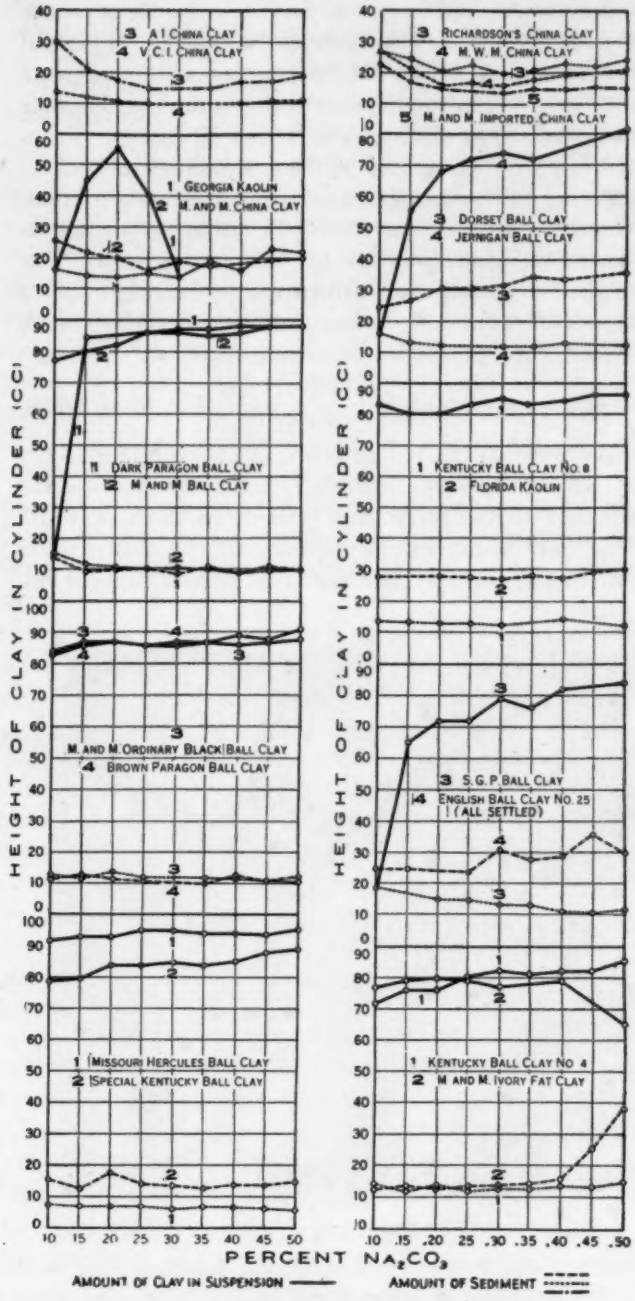
3 A I CHINA CLAY
4 V C I CHINA CLAY
1 GEORGIA KAOLIN
2 M. AND M. CHINA CLAY
1 DARK PARAGON BALL CLAY
2 M AND M BALL CLAY
3 M. AND M. ORDINARY BLACK BALL CLAY
4 BROWN PARAGON BALL CLAY
1 MISSOURI HERCULES BALL CLAY
2 SPECIAL KENTUCKY BALL CLAY
3 RICHARDSON'S CHINA CLAY
4 M. W. M. CHINA CLAY
5 M. AND M. IMPORTED CHINA CLAY
3 DORSET BALL CLAY
4 JERNIGAN BALL CLAY
1 KENTUCKY BALL CLAY NO. 8
2 FLORIDA KAOLIN
3 S.G.P. BALL CLAY
4 ENGLISH BALL CLAY NO. 25
(ALL SETTLED)
1 KENTUCKY BALL CLAY NO. 4
2 M AND M. IVORY FAT CLAY
HEIGHT OF CLAY IN CYLINDER (CC)
PERCENT Na_2CO_3
AMOUNT OF CLAY IN SUSPENSION
AMOUNT OF SEDIMENT

FIG. 4.—Deflocculation tests of clays 10g/100cc.

tion of gases about each piece. The temperature of the kiln was raised according to the curve shown in Fig. 2 and held for 5 hours at 700°C. After the kiln had cooled the pieces were broken transversely and the cross-sectional areas of the unoxidized portions determined by means of a planimeter. The appearances of the test pieces are shown in Fig. 3.

10. Determination of True Specific Gravities

In making true specific gravity determinations with the pycnometer, there are two possible courses, (1) to run all determinations at a constant temperature, or (2) to calibrate the pycnometers for thermal expansion. Since it was difficult to keep

the temperature constant, the pycnometers were calibrated for thermal expansion in the following manner.

The volume of each pycnometer was determined by weighing the pycnometer filled with water at three or four different temperatures. Pure distilled water from which the air had been removed by boiling in a partial vacuum was used. The densities of water used in the calculation of the volumes were as given in standard physical tables. The curves obtained by plotting volumes against temperatures were found to lie very nearly in a straight line. The average expansion for a 50 cc pycnometer is 0.0018 cc per °C, but varies widely for different kinds of glass; consequently unless this expansion is taken into account a serious error will be introduced.

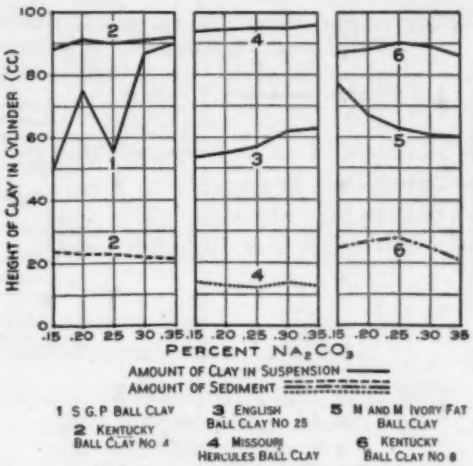
HEIGHT OF CLAY IN CYLINDER (CC)
100
80
60
40
20
0
.15 .20 .25 .30 .35 .15 .20 .25 .30 .35 .15 .20 .25 .30 .35
PERCENT NA_2CO_3
AMOUNT OF CLAY IN SUSPENSION
AMOUNT OF SEDIMENT
1 S G P BALL CLAY
2 KENTUCKY BALL CLAY NO 4
3 ENGLISH BALL CLAY NO 25
4 MISSOURI HERCULES BALL CLAY
5 M AND M IVORY FAT BALL CLAY
6 KENTUCKY BALL CLAY NO 8

FIG. 5.—Deflocculation tests of clays 20g/100cc.

The fired test pieces previously dried at 110°C were crushed in a diamond steel mortar and then ground in an agate mortar. The powder so obtained was sieved on a Tyler-Rotap, and that fraction which passed a 100-mesh sieve and remained on a 300-mesh sieve was used. All particles of iron were removed with a magnet.

Five to eight grams of powder were introduced into the pycnometer whose weight and volume had been determined. The pycnometer and powder were weighed with an accuracy of .0001 g. Enough water was poured into the pycnometer to barely cover the powder and this was boiled under a vacuum at room temperature, in order to liberate the entrapped air. The pycnometer was then filled with water that had been previously boiled under a vacuum and was allowed to stand in a water bath until it was nearly at room temperature. The temperatures were taken with an accuracy of $\frac{1}{10}$°C. From the above data the true specific gravity was obtained. Duplicate determinations were made on each sample and all that differed more than 0.005 were repeated.

NOTE: For derivations of formulas for open and closed pores see *Trans. Amer. Ceram. Soc.*, **9**, 211 (1907), **10**, 365 (1908), **11**, 60 (1909).

Malachite Green Determinations

The malachite green determinations were not entirely satisfactory, since there was so little difference in the adsorption of the dye by the different ball clays.

Certain impurities in the clays will decompose malachite green and consequently the impure clays such as ball clays will be affected more than the pure clays. The adsorption tests with the china clays were more satisfactory. In general, the greater the adsorption of the dye by this class of clays, the greater was the plasticity in the raw state and the lower the porosity when fired at a given cone temperature.

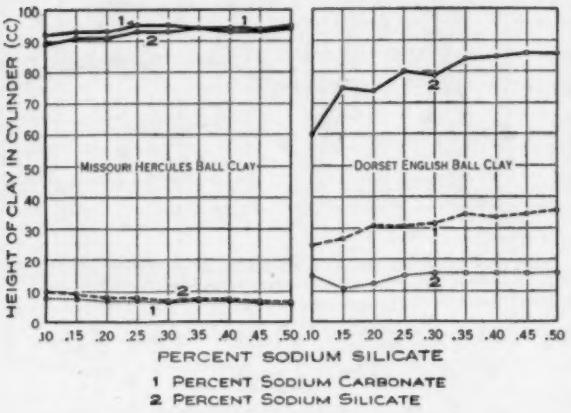
HEIGHT OF CLAY IN CYLINDER (CC)
MISSOURI HERCULES BALL CLAY
DORSET ENGLISH BALL CLAY
PERCENT SODIUM SILICATE
1 PERCENT SODIUM CARBONATE
2 PERCENT SODIUM SILICATE

FIG. 6.—Deflocculation tests of clays using sodium silicate and sodium carbonate.

From the adsorption results shown in Table I it is easy to group the clays in three classes: (1) true kaolin or china clays, (2) sedimentary kaolins, and (3) ball clays. The only exceptions are the Jernigan ball clay and M.W.M. china clay, the latter being an English china clay.

Deflocculation Tests

These tests were made in order to determine the effect of electrolytes on the deflocculation of ball and china clays.

There were four ways in which the ball clays and Georgia kaolin reacted with the electrolyte.

1. The amount of clay in suspension remained fairly constant for all percentages of electrolyte added.

These clays are arranged in order of their suspension in solutions with sodium carbonate as the electrolyte.

Missouri Hercules ball clay	92 to 95 cc of a possible 100 cc
M&M ordinary black	85 to 91 " " " " " "
Brown "Paragon" ball clay	" " " " " " " " "
Kentucky ball No. 8	82 to 86 " " " " " "
Kentucky ball No. 4	72 to 85 " " " " " "

2. The clays varied in their suspension conduct according to the concentration of the electrolyte.

The following clays are arranged in the order of the effect produced by sodium carbonate as the electrolyte:

	Variation in suspension
Dark "Paragon" ball clay	15 to 88 cc out of a possible 100 cc
S.G.P. ball	20 to 83 " " " " " " "
Jernigan ball	27 to 81 " " " " " " "

The effect of the electrolyte was most marked with the dark "Paragon" ball clay as there was a very large increase of clay in suspension with a change from .10% to .15% of sodium carbonate as electrolyte.

3. The clays showed a maximum deflocculation which was followed by flocculation.

M&M ivory fat clay
Georgia kaolin

This was more noticeable with the clay slips which contained 20 g of clay in 100 cc of water than in those which contained 10 g of clay in 100 cc of water.

4. The clays failed to remain in suspension at any concentration of the electrolyte.

Dorset English ball clay
English ball clay No. 25

With an increase in concentration of clay from 10 to 20 grams per 100 cc the English ball clay No. 25 stayed in suspension from the 50 to the 65 cc mark depending upon the percentage of electrolyte used. Sodium silicate caused the Dorset ball clay to deflocculate.

Electrolytes had practically no effect on the china clays.

Maximum deflocculation of the Georgia kaolin was produced by .2% of Na_2CO_3. Either an increase or decrease in the concentration of the electrolyte caused a settling.

Microscopic Examination of the Fired Clays

Typical clays of various types were selected for this examination. The detection of mullite in fired clays is difficult and at best can be detected with high magnification only. The writers used an oil immersion objective and detected the mullite by inserting a red of the first order gypsum plate between crossed nicols. The mullite appeared as fibrous crystals with parallel extinction and positive elongation. In some cases crystals were formed which were large enough to be more thoroughly examined.

Clay No. 22 Missouri Hercules Ball Clay (washed) Samples fired to cones 6, 10, 12 and 14 were examined. This clay was characterized by the large amount of quartz present. The quartz grains were transparent and remarkably free from inclusions. The grains became more rounded and corroded with increased firing temperatures. A small amount of mullite could be detected at cone 12, and at cone 14 there was a considerable amount present.

Clay No. 30 M&M Ball Clay The fired clay samples showed the presence of a very small amount of mullite at cone 10. At cone 14 the few quartz grains present were corroded and there was slightly more mullite present.

Clay No. 31 Ky. Ball Clay No. 4 This clay showed the presence of mullite at cone 10 and the amount increased with increased temperature. There was a larger amount of mullite present in this clay than in any of the other ball clays examined.

Clay No. 16 Florida Kaolin There was very little mullite detected in the clay fired at cone 12; however, there was considerable quartz present. At cone 14 considerable mullite was present and the quartz grains were more rounded.

Clay No. 13 M. W. M. China Clay Mullite was present in large amounts at cone 14. The mullite crystals were better developed than in any of the other clays studied.

Summary of the Data Relating Particularly to the Ball Clays[1]

Water of Plasticity There are differences of only 2 or 3% between the amounts of water of plasticity of the crude and the washed samples, excepting the S.G.P. ball clay in which case it amounts to about 8%. When these clays are arranged in the order of increasing values, the water of plasticity in the crude and the washed samples is as follows:

	Crude	Washed		Crude	Washed
Missouri Hercules	30.3	31.8	Jernigan B	40.4	38.8
*M&M ivory fat	30.6	31.0	*English ball No. 25	40.9	42.4
*M&M ball	34.2	35.7	*M&M ordinary black	42.6	42.1
*Dorset	38.2	39.6	Kentucky No. 8	44.3	44.6
*Brown "Paragon" ball	39.1	38.3	Kentucky No. 4	46.5	46.0
*Dark "Paragon" ball	40.0	43.3	Special Kentucky	49.4	54.8
S.G.P.	40.2	48.2			

* English clays.

On the whole, American clays have a higher water of plasticity than the English ball clays.

Volume Drying Shrinkages These arranged in the order of increasing values of the crude material are as follows:

[1] For complete test data and descriptions of test see Appendix.

	Crude	Washed		Crude	Washed
Missouri Hercules	18.3	20.3	*M&M ordinary black	24.7	25.7
S.G.P.	20.6	25.0	Kentucky No. 8	25.3	25.9
*Dark "Paragon" ball	21.2	26.1	*English No. 25	25.8	28.6
*M&M ball	21.9	24.5	Kentucky special	26.5	30.3
*M&M ivory fat	22.2	22.7	Kentucky No. 4	29.0	26.8
Jernigan	22.3	20.7	*Dorset	35.7	27.6
*Brown "Paragon" ball	24.4	25.7			

* English Clays.

There seems to be no important difference between he English and the domestic clays as such. Generally the washed materials show higher shrinkages, although the differences ordinarily are slight. The exceptions are Jernigan, Kentucky No. 4, and Dorset.

Shrinkage Water When the crude clays are arranged according to their shrinkage water content in the order of increasing values they are as follows:

	Crude	Washed		Crude	Washed
Missouri Hercules	12.7	14.3	*M&M ordinary black	20.4	20.4
*M&M ivory fat	15.5	15.1	*Dorset	20.5	21.4
*M&M ball	16.1	18.0	*English No. 25	21.2	22.8
S.G.P.	17.2	21.5	Kentucky No. 8	22.0	22.6
*Dark "Paragon" ball	17.3	21.6	Kentucky No. 4	24.5	22.5
Jernigan	18.1	15.6	Special Kentucky	24.8	28.8
*Brown "Paragon" ball	19.7	20.0			

* English Clays.

American clays are found with both the highest and the lowest shrinkage water contents. In general, the shrinkage water is less in crude material than in the washed material, excepting the M&M ivory fat, Jernigan, and Kentucky No. 4. Ordinarily the differences between the values of the washed and the crude clays are small and probably of no significance.

Pore Water The crude clays have been tabulated in order of increasing pore water content.

	Crude	Washed		Crude	Washed
*Dark "Paragon" ball	12.1	21.7	*English No. 25	19.7	19.6
*M&M ivory fat	15.0	15.9	Kentucky No. 4	22.0	23.5
Missouri Hercules	17.6	17.5	Kentucky No. 8	22.3	22.0
*Dorset	17.7	18.5	*M&M ordinary black	22.3	21.7
*M&M ball	18.1	17.7	Jernigan	22.3	23.1
*Brown "Paragon" ball	19.4	18.3	S.G.P.	23.0	26.7
			Special Kentucky	24.6	26.0

* English Clays.

Generally there are only small differences between the crude and the washed clays, sometimes one and sometimes the other is larger. A notable difference is observed in the case of dark "Paragon" ball clay. The American clays show higher values.

Ratio of Pore Water to Shrinkage Water

The crude clays have been tabulated according to an increasing order. The English clays are chiefly below 1 : 1 ratio. Washed clays have lower ratios than crude clay with a few exceptions.

	Crude	Washed		Crude	Washed
S.G.P.	1.33	1.24	*Brown "Paragon" ball	0.98	0.91
Missouri Hercules	1.38	1.22	*M&M ivory fat	0.97	0.95
Jernigan	1.23	0.66	*English No. 25	0.93	0.85
*M&M ball	1.19	0.98	Kentucky No. 4	0.90	1.05
*M&M ordinary black	1.10	1.23	*Dorset	0.86	0.85
Kentucky No. 8	1.02	0.97	*Dark "Paragon" ball	0.72	1.0
Special Kentucky	1.00	0.90			

* English Clays.

Bulk Density of Dry Clay

These have been arranged in the order of the increasing values of the crude materials. The washing of clays has the effect of increasing the density. English clays generally have higher values than domestic clays.

	Crude	Washed		Crude	Washed
Special Kentucky	1.49	1.53	*Brown "Paragon" ball	1.67	1.76
S.G.P.	1.54	1.57	*English ball No. 25	1.71	1.80
Kentucky No. 8	1.58	1.67	*M&M ball	1.72	1.80
*Dark "Paragon" ball	1.60	1.66	Missouri Hercules	1.76	1.81
Jernigan	1.60	1.69	*Dorset	1.77	1.82
Kentucky No. 4	1.60	1.66	*M&M ivory fat	1.85	1.92
*M&M ordinary black	1.61	1.72			

* English clays.

Modulus of Rupture

The modulus of rupture of the washed clays are tabulated in the following table according to the increasing order of values.

	Washed		Washed
Jernigan	284	Kentucky special	575
S.G.P.	289	*M&M ivory fat	592
*M&M ball	464	*Brown "Paragon" ball	685
*English No. 25	492	*Dorset	744
Kentucky No. 8	500	*M&M ordinary black	757
Kentucky No. 4	530	*Dark "Paragon" ball	819
Missouri Hercules	538		

* English clays.

The minimum is 284 lbs. per square inch and the maximum 819 lbs. The English clays gave the highest values with the exceptions of M&M ball clay and ball clay No. 25. It is of interest to note that our values for Kentucky No. 4 and for Dorset are higher than those which have been published in *Technical Paper*, No. 227 of the Bureau of Standards, which publication reports the former showing a value of 372 lbs. per square inch and the latter 492 lbs. per square inch. We are assuming that the Dorset clay indicated is of the same origin as that which we tested. These discrepancies are probably explained by the differences in the conduct of the tests and differences in the apparatus used, inasmuch as it has been observed that such tests are very susceptible to comparatively insignificant changes in the technique.

Volume Firing Shrinkages: Crude Ball Clays

The clays have been divided into two groups according to changes taking place in volume shrinkages during firing. These groups (Fig. 7) are (*A*) those which show continuous shrinkage at all temperatures, varying somewhat in amount, but having similar rates of change. Only one English ball clay is included in the group. (*B*) Those clays which reach a maximum and then show decrease in shrinkage, that is, expansion after cone 12. These generally show less shrinkage up to cone 12 than those included in group (*A*), excepting Jernigan clay which is very high. With the exception of this clay all the others are of English origin and it should be noted that in certain individual cases the variation in shrinkage is extremely small.

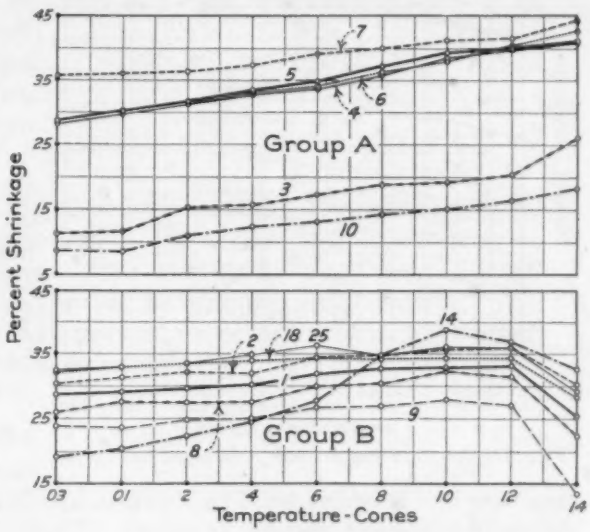

FIG 7.—Volume firing shrinkages. Crude ball clays.

Washed Ball Clays

The volume shrinkage of the washed ball clays (Fig. 8) is very much the same as described for the crude clays. The notable exception is S.G.P. clay which shows a greatly increased shrinkage at all cones. Dark "Paragon" ball shows a slight indication of swelling after cone 12 which is not regarded as of sufficient magnitude to be important.

Apparent Porosity of Ball Clays

The Dorset clay shows zero porosity at cone 2 with a remarkably long firing range, and slight indication of overfiring at cone 14. M&M ivory fat, English No. 25, Brown "Paragon" ball, and M&M ordinary black reach zero porosity at cone 6. M&M ball is nearly nonporous at that stage. Dark "Paragon" ball and Jernigan become nonporous at cone 10. Kentucky ball No. 8 and Kentucky ball No. 4 reach the same stage at cone 12, S.G.P. ball clay and Missouri Hercules do not reach nonporous condition at any temperature attained. Most of the clays (Fig. 9) show signs of overfiring to a greater or less degree after passing cone 12.

The conduct of the washed clays is very similar. (Fig. 10).

Total Porosity Ball Clays

The crude ball clays (Fig. 11) may be divided into two groups, (*A*) those which do not show any signs of overfiring at any temperature. The porosity shows a steady drop throughout the whole range with the exception of dark "Paragon" ball which shows a halt at cone 10.

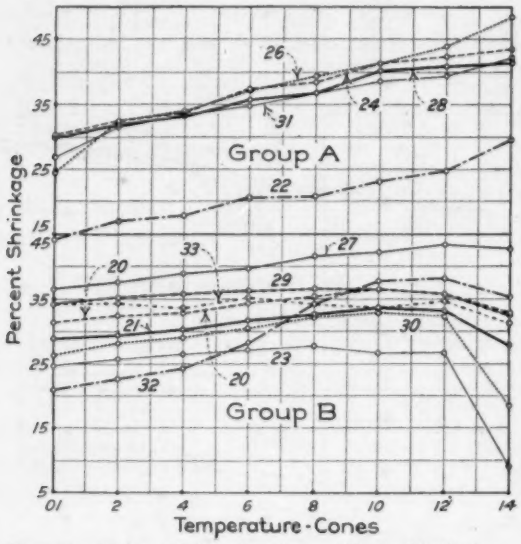

FIG. 8.—Volume firing shrinkage. Washed ball clays.

(*B*) Those clays which show definite signs of overfiring after cone 12. In this group, we find all the English clays, excepting dark "Paragon" ball, and one domestic clay, namely, Jernigan.

The washed clays show the same characteristics as the crude clays varying only in degree. (Fig. 12.)

True Specific Gravities

These may be divided into three groups. (Figs. 13 and 14) Group 1, which contains those clays whose true specific gravities show a marked acceleration in the rate of decrease of specific gravity at cone 6. These clays are S.G.P., Missouri Hercules, and Jernigan.

Group 2. These clays reach a minimum point which is then followed by an increase. The clays are Kentucky No. 4, Kentucky No. 8 and, Special Kentucky. The last named shows the increase only with the washed sample.

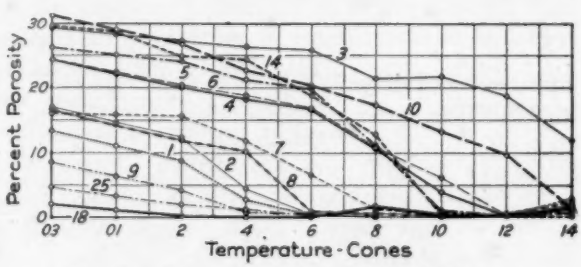

FIG. 9.—Apparent porosity. Crude ball clays.

Group 3. The remaining clays have been gathered in this group. It seems probable that the Dorset and the English No. 25 should be placed by themselves. The other clays have some

* For identification of clays by numbers given in all graphs see paragraph "Properties of Individual Clays," p. 612 or Table I.

striking similarities but the differences between the washed and the crude samples of the same clay are sometimes too great to permit a close classification; for example, M&M ball clay. It should be noted that in this group, however, the rate of change of the specific gravity is diminished after passing cone 6 and accelerated again after cone 12.

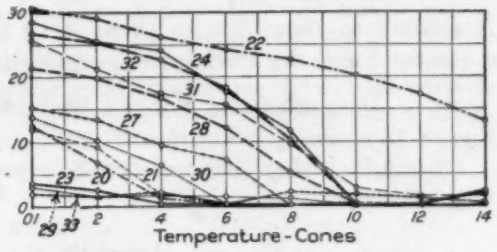

FIG. 10.—Apparent porosity. Washed ball clays.

It is very probable that the rate of the development as well as the amount of mullite, have a marked influence upon the conduct of these clays, inasmuch as the mullite has a specific gravity of 3.08. When the mullite increases the specific gravity tends to rise. An increase in the amount of the glass tends to diminish the specific gravity. The true china clays show a large amount of mullite developed and an increase in specific gravity.

Color In comparison of the colors of the several ball clays attained at cone 8 results may be tabulated as follows:

	w	−c	c	+c	++c
American	2	1	1	2	
English		1		3	2

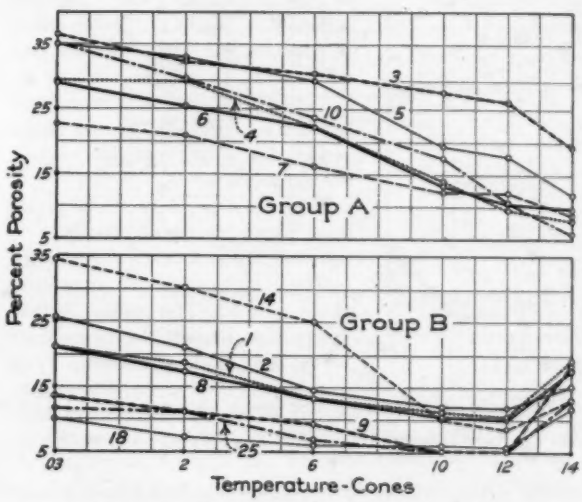

FIG. 11.—Total porosity. Crude ball clays.

This seems to indicate that the domestic clays are whiter than the imported clays at this cone. The significance of the symbols of w, c, etc., is shown on Table IX.

Carbon Content A comparison of the carbon content of the clays is shown by results of the oxidation firing. (See Fig. 3.) This seems to indicate that the clays may be arranged in the following order with the maximum first.

*M&M ordinary black
Special Kentucky
*Dark "Paragon" ball clay
*Brown "Paragon" ball clay
Missouri Hercules
Kentucky No. 8
Kentucky No. 4
* English clays.

*English No. 25
*M&M ball clay
Jernigan
*Dorset
S.G.P.
*M&M ivory fat

According to these results there is very little difference between the domestic and the foreign clays in this particular.

Porosities and Volume Shrinkage of Kaolins

Figure 16 showing porosities of china and sedimentary clays, and Fig. 15 volume firing shrinkage of true and sedimentary kaolins do not need any comment.

Appendix

Properties of the Individual Clays

Ball Clays

Brown "Paragon" Ball Clay
Crude, Sample No. 1
Washed, Sample No. 21

This clay was a medium brown color. There was 1.52% of residue retained on 120-mesh screen which consisted of lignite, clay, and some quartz. The plasticity and working qualities were excellent but there was a slight tendency for the clay bars to warp on drying. The malachite green test indicated that the clay was very fine-grained. The deflocculation tests showed that it remained well in suspension for all proportions of electrolyte added, there being no large increase or decrease of deflocculation with varying amounts of Na_2CO_3. The modulus of rupture was high, 658 lbs. per sq. in.

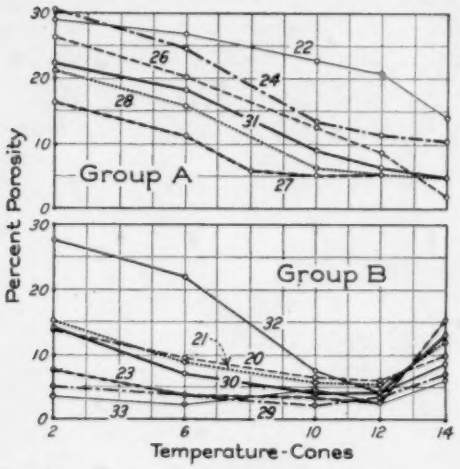

FIG. 12.—Total porosity. Washed ball clays.

The clay cylinders were difficult to oxidize, only 55% of the cross-section being oxidized at the end the oxidation firing.

The open porosity of the crude fired pieces decreased virtually to zero at cone 6 and there were marked indications of overfiring above cone 12. The volume shrinkage and closed pore determinations verify the above statement. The color of the fired pieces was a light cream which became darker with increase of temperature to cone 12 where blue-stoning occurred. This clay was similar to M&M ordinary black ball clay.

The washed sample had similar characteristics. The volume shrinkages were practically the same as with the crude clay. After passing cone 2, the washed clay showed a sharper drop in porosity and the total porosity was nearly 5% lower above cone 5 than with the crude clay. Overfiring was indicated at cone 12.

The true specific gravities of the crude and the washed clays were very much alike at all temperatures. The apparent and the bulk specific gravities of the crude clay were 0.1 unit lower at all temperatures.

The percentage of closed pores of the crude clay was considerably higher at all temperatures.

M&M Ordinary Black Ball Clay
Crude, Sample No. 2
Washed, Sample No. 20

This clay was a dark brown color. There was 1.22% of residue retained on a 120-mesh lawn which consisted mainly of lignite and particles of clay. The malachite green test indicated that the clay was fine-grained. The plasticity and working properties were good. There was a tendency to warp during drying. The clay remained in suspension with all percentages of electrolyte added. The modulus of rupture was high, being 757 lbs. per sq. in.

Only 49% of the clay cylinders were oxidized at the end of the firing.

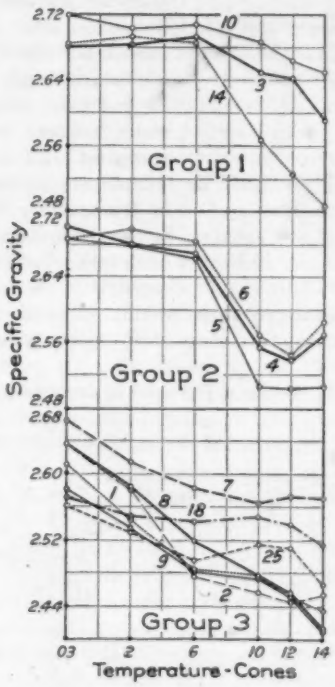

FIG. 13.—True specific gravities. Crude ball clays.

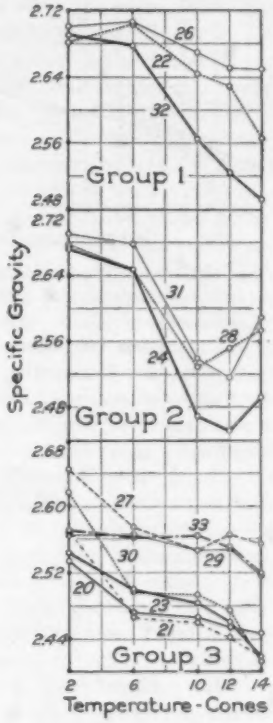

FIG. 14.—True specific gravities. Washed ball clays.

The washed clay test pieces had a low porosity at cone 3, while the crude clay pieces did not reach a low porosity until cone 6 was reached. They both show the characteristic signs of overfiring at cone 14. The volume shrinkage was not affected by the washing. The color of the fired pieces was excellent and varied from a light to dark cream color as the temperature of firing increased. Only the pieces made from the crude clay showed evidences of blue-stoning at cone 14.

The true specific gravities of the crude and the washed clays were practically the same at all temperatures. The bulk and the apparent specific gravities of the crude clay were about 0.15 units lower at cone 4 or above.

The percentage of closed pores was approximately 5% higher in the crude clay at cone 4 and above.

The washed clay pieces showed no evidences of scum or discoloration while the crude clay pieces after firing to cones 03 and 01 if saturated in water and allowed to dry, showed a small amount of green scum.

Missouri Hercules Ball Clay
Crude, Sample No. 3
Washed, Sample No. 22

The color of this clay was nearly black. A residue which consisted chiefly of rounded quartz grains with some lignite was retained on a 120-mesh sieve to the amount of 6.1%. This clay remained in suspension the best of any tested. An increase of the percentage of electrolyte had very little effect on the amount of clay in suspension. The plasticity was only fair, as it had a rather rubbery consistency when wet and it was exceedingly difficult to maintain a uniform water content even by wedging and storing. There were no difficulties in drying either the crude or the washed clay. The malachite green test indicated that the clay was not very fine-grained but much finer than that of any of the residual china clays tested. The modulus of rupture of a mixture containing an equal weight of flint was moderate, being 537.6 lbs. per square inch.

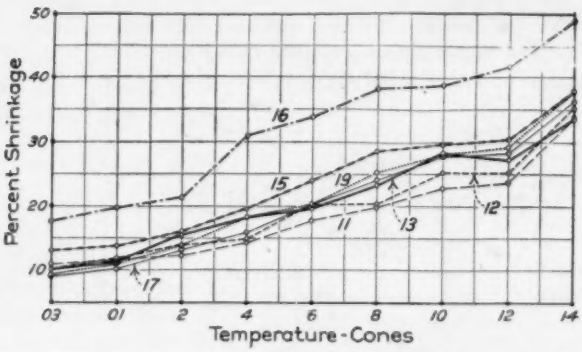

FIG. 15.—Volume firing shrinkage. China clays and sedimentary kaolins.

In the oxidation firing 76% was oxidized. Missouri Hercules is peculiar in that it is an exceedingly open firing ball clay. The changes in the porosities and the volume shrinkages are very gradual and the clay is not vitrified at cone 14. For this reason it can be substituted for some of the china clay in a porcelain body. There is little difference (about 5%) between the porosities of the crude and the washed clay at all temperatures. The volume shrinkages differ by less than 5%. This clay developed a better color when fired than any of the other ball clays.

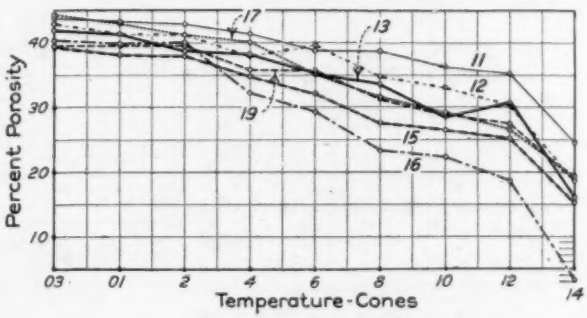

FIG. 16.—Apparent porosity. China clays and sedimentary kaolins.

The true specific gravities of the crude and the washed clays are practically the same.

The true and the apparent specific gravities of the washed clay do not differ until cone 2 is passed and then not greatly until cone 10 is passed, an unusual occurrence.

The apparent and the bulk specific gravities of the washed clay are lower.

The content of closed pores is much higher in the crude clay.

Kentucky Ball Clay No. 8
Crude, Sample No. 4
Washed, Sample No. 28

This clay was a clean light brown color. There was .23% of residue retained on a 120-mesh lawn which consisted of carbonized wood, granules of clay, and a few grains of quartz. The plasticity and working properties of this clay were good. The deflocculation tests showed that it remained well in suspension for all proportions of electrolyte. The drying conduct was fair, with only a slight tendency to warp but no cracking. The modulus of rupture of a mixture containing an equal weight of flint was good, being 500 lbs. per square inch. Eighty-one per cent was oxidized at the end of five hours. A dark gray core remained at the center of the cylinder.

Kentucky Ball Clay No. 4
Crude, Sample No. 6
Washed, Sample No. 31

This clay was very similar to Kentucky ball No. 8 in all its properties. In the deflocculation test Kentucky ball No. 8 remained in suspension a little better and the fineness as determined by malachite green adsorption was almost identical. The drying conduct of the two clays was similar. The modulus of rupture was 530 lbs. per sq. in. which was a trifle higher than No. 8.

The total porosities of the fired pieces of the crude clay decreased from 28.5% at cone 03 to 7.7% at cone 14. The behavior of the washed clay was practically the same except that the porosities were lower than in the case of the crude clay. The total pore volume reached 4.5% at cone 14. The volume shrinkages increased steadily with increased temperature and there was very little difference between the washed and the crude clays. The apparent specific gravity and the bulk specific gravity curves of the crude and the washed clays came very close at cone 12. The closed pores showed a maximum at cone 12 and there were no indications of over-firing at cone 14. The washed clay bars cracked badly in firing.

The bars made from the washed clay developed a better color than those made from the crude clay. The crude clay bars showed a slight blue-stoning at cone 8, while the washed clays did not develop blue-stoning until cone 12 was reached. The green stain possibly due to vanadium salts was conspicuous until cone 8 was reached. Above this temperature the stain did not appear. This coloration was much more pronounced on the test pieces made from the crude clay.

The true specific gravities of the crude and the washed clays are identical. The apparent and the bulk specific gravities of the washed clay are slightly higher (0.05 to 0.1 units). The closed pore content in the washed clay is less.

A comparison of Kentucky ball clays No. 8 and No. 4 shows that the crude clays have practically identical volume shrinkages, total porosities, open pore content, true, apparent, and bulk specific gravities. The No. 4 clay has a lower content of closed pores.

The washed clays show practically identical volume shrinkages and total porosities and open porosities differ in the respective clays by 5% or less. The true, apparent, and bulk specific gravities and volumes of closed pores differ very little.

The rates of oxidation were practically the same. Kentucky ball clay No. 8 reached a slightly lower porosity at the same firing temperature. If anything the colors of the fired bars made from Kentucky ball No. 4 had a better color than those made from Kentucky ball No. 8 and there was less of the green stain present.

Special Kentucky Ball Clay,
Crude, Sample No. 5
Washed, Sample No. 24

The color of this clay was a dark-reddish brown. There was 1.32% of residue of clay and carbon that failed to pass a 120-mesh screen. The malachite green test indicated that the clay was fine grained. The plasticity and working properties were fair and there was only a slight tendency to warp in drying. The clay remained fairly well in suspension for all proportions of the added electrolytes. The modulus of rupture was 575 lbs. per sq. inch which was higher than for any of the other Kentucky ball clays examined. Only 52.5% of the cross-sections of the cylinders were oxidized at the end of the oxidation firing.

The porosity and volume shrinkage curves were very similar in shape to those of the Kentucky ball No. 4 and Kentucky ball No. 8, except that the washed special Kentucky ball reached a low porosity at cone 10. There was very little difference in the firing behavior of the crude and the washed clay. The colors of the fired test pieces were good although the crude clay showed signs of blue-stoning at cone 8, while the washed clay did not show blue-stoning until cone 12 was reached.

The crude and the washed clays were similar in volume shrinkages, percentage content of open porosities, and true specific gravities. The total porosities and closed pores were higher in the crude clay. The bulk and the apparent specific gravities were lower in the crude clay.

Dark "Paragon" Ball Clay
Crude, Sample No. 7
Washed, Sample No. 27

This clay was a dark brown color. There was 1.32% residue retained on a 120-mesh lawn which consisted mainly of carbonized wood and quartz. The plasticity and working properties were fair, but the clay seems to be somewhat rubbery in consistency when wet. It works well through a die. There is a slight tendency for the clay to warp in drying. It remains well in suspension when .15% of electrolyte is added and a further addition of electrolyte does not make any appreciable change.

The modulus of rupture of a mixture containing an equal amount of potters flint was 819 lbs. per sq. in. which was the highest value attained by any clay.

Only 59% of the area of the cylinders were oxidized during the oxidation firing.

The open porosity of the fired pieces of the crude clay decreased to 1.27% at cone 8 and it showed a very slight evidence of overfiring above cone 12.

The behavior of the washed clay was about the same, except that the porosity values were lower at each cone temperature. Practically zero porosity was reached before cone 7. There was very little change in the volume shrinkage with increased temperatures. It had the characteristics of an English clay. The washed clay bars cracked badly in firing. The bars made from the washed clay had a better color than those made from the crude clay, but each showed an indication of blue-stoning at cone 12. A brown stain was noticeable on the briquettes fired to cone 6 and above.

Washing the clay had little effect upon the volume shrinkage. The total porosities were decreased by practically 5%. The open porosities at temperatures lower than cone 6 were somewhat decreased.

The true specific gravities of the washed and the crude clays were practically the same. The apparent and the bulk specific gravities of the washed clay were slightly greater. The content of closed pores in the washed clay was less.

Ball Clay C
Crude, Sample No. 8
Washed, Sample No. 30

This clay was a mixture of lumps, light and dark gray in color. There was .28% of residue retained on a 120-mesh sieve which consisted of lignite, mica, quartz, roots, mineral debris, and clay. This clay had high plasticity and excellent working properties. In the deflocculation tests it remained fairly well in suspension for all proportions of added electrolyte and the malachite green determinations showed that it was a fine-grained clay. The drying conduct was fair as there was only a slight tendency for the clay to crack in drying. The modulus of rupture of a mixture containing an equal weight of flint was 464 lbs. per sq. in. which was below the average for the ball clays tested.

The clay cylinders were nearly but not entirely oxidized at the end of the oxidizing firing, a light gray core remaining.

The open porosities of the fired pieces of both the crude and the washed clays decreased to nearly zero at cone 6 and remained constant to cone 12. Above cone 12 the volume shrinkage, open porosity, and closed pores indicated decided overfiring. Some of the washed clay bars cracked badly in firing.

The washed clay had a better color when fired than the crude clay. Blue-stoning developed at cone 12 for the crude clay but the washed clay did not show it. There was only a trace of green scum on the crude clay bars fired to cone 03.

M&M Ivory Fat, Crude, Sample No. 9 Washed, Sample No. 23

The crude clay was a light cream color. There was .11% of residue retained on a 120-mesh screen. The malachite green test indicated that the clay was very fine-grained. The plasticity was high but the clay was too fatty to have the best working properties. It tended to warp and crack in drying and the drying volume shrinkage was high. The modulus of rupture with an equal weight of flint was good, being 592 lbs. per square inch.

The deflocculation tests showed that the clay remained fairly well in suspension except the sample containing .5% Na_2CO_3 which showed a coagulation.

The clay cylinders were completely oxidized at the end of the oxidation firing.

The open porosity of the clay showed a drop to practically zero at cone 4 for the crude and cone 3 for the washed. At cone 14 there was a decided evidence of overfiring as indicated by the porosity, volume shrinkage, and closed pores.

The bars made from both the crude and the washed clays had a good cream color which deepened in shade with increasing temperature. The crude clay developed blue-stoning at cone 12 which did not appear in the washed clay until cone 14 was reached.

Washing the sample had slight effect upon the volume shrinkage but decreased the per cent total porosities and open porosities at low temperatures. Washing increased the apparent and the bulk specific gravities slightly.

S.G.P. Ball Clay Crude, Sample No. 10 Washed, Sample No. 26

The crude clay was light gray in color. There was .21% of residue retained on a 120-mesh screen which consisted mainly of quartz, lignite and rootlets. The malachite green tests indicated that the material was not very fine-grained. The plasticity was rather low, the drying conduct was fair and there was only a slight tendency to warp. The modulus of rupture of a mixture containing an equal weight of flint and clay was the next to the lowest of any clay tested, being only 289 lbs. per sq. in.

The results of the deflocculation tests were rather erratic. It required .35% Na_2CO_3 to keep the clay well dispersed.

The clay cylinders were completely oxidized at the end of the oxidation firing.

The porosity curves showed a continuous drop throughout the range of temperature and the crude and washed clays approached within 5% of complete vitrification at cone 14, at which temperature there were no signs of over-firing.

The bars made from both the crude and the washed clays were of a light cream color when fired, the shade becoming deeper until cone 14 was reached, at which temperature there was marked blue-stoning.

The bars fired at low temperatures were badly stained with the characteristic green generally ascribed to vanadium salts. At cone 10 this coloration disappeared from the crude clay bars and was just noticeable in those made from the washed clay. The stain on the crude clay bars was very much greater in amount than on the washed clay bars. The bars made from the washed clays cracked very badly in firing.

The washed clay had about 5% greater volume shrinkages at all temperatures and averaged about 5% less open and total porosities than the crude clay at all temperatures. At cone 14 the open porosities differed very little.

The true specific gravities of the crude and the washed clays were practically the same and the apparent and bulk specific gravities of the washed clay were somewhat higher. The percentage of closed pores diminished in the washed clay.

Jernigan Ball Clay Crude, Sample No. 14 Washed, Sample No. 32

The crude clay was dark brown in color. There was only .06% of material which failed to pass a 120-mesh lawn. The malachite green tests indicated that either the ball clay was coarse grained or that there were compounds in the clay which

decolorized the malachite green solution. The clay required .5% of Na_2CO_3 before it remained well in suspension. The plasticity was only fair and it was rather difficult to get a uniform moisture content. The drying conduct was good, there was no cracking and only slight warping. The modulus of rupture of clay-flint mixtures was the lowest of any clay tested, being 284 lbs. per sq. inch. The clay cylinders were completely oxidized at the end of the oxidation firing.

The porosity of both the crude and the washed clays reached approximately zero at cone 10 and remained constant throughout the remainder of the firing.

The volume shrinkage of the crude clay showed definite indications of overfiring at cone 10. This did not appear in the washed clay until cone 12. The total porosity curves of both crude and washed clays showed overfiring at cone 12.

The open pore content was only slightly affected by washing and the total porosity of the crude clay was slightly greater.

The true specific gravities of the crude and the washed clays were very nearly identical. The apparent specific gravity of the washed clay was notably higher while the bulk specific gravity was only little changed.

The content of closed pores in the washed clay was less. Some of the bars made from the washed clays cracked in firing. The colors of the fired bars made from crude clay were darker than those made from the washed clay. Blue-stoning was pronounced at cone 10. The crude clay bars were covered with a large amount of scum which was green at low temperatures and brown at high temperatures. This was largely absent on the fired bars made from the washed clay.

Dorset English Ball
Crude, Sample No. 18
Washed, Sample No. 33

The crude clay was a mixture of lumps of light and dark gray color. There was only .03% of material that failed to pass through as 120-mesh. The malachite green test indicated that the clay was very fine grained. This clay had a high plasticity but was rather difficult to wedge as the different layers tended to laminate. The drying conduct was poor due to cracking and warping. The deflocculation tests showed that the clay would not remain in suspension with sodium carbonate. The modulus of rupture of a mixture of equal weights of flint and clay was high, being 744 lbs. per sq. inch.

The clay cylinders were completely oxidized at the end of the oxidation firing.

The sample of crude clay fired at cone 03 had 2½% open porosity and this decreased to practically zero at cone 2. Beyond cone 12 overfiring was indicated. The washed clay showed a similar conduct.

The volume shrinkages and true specific gravities of the washed and the unwashed clays were practically identical. The total porosities and percentages of closed pores of the crude clay were slightly greater. The apparent and the bulk specific gravities of the washed clay were higher. Blue-stoning was first developed at cone 10. The colors of the fired briquettes below this temperature were dark cream for the crude clay and brownish gray for the washed clay. The bars made from both washed and crude clays cracked badly in firing.

English Ball Clay
Crude, Sample No. 25
Washed, Sample No. 29

This clay had a light gray color. There was only .11% of material which failed to pass a 120-mesh lawn. The plasticity and working properties of this clay were excellent. The clay completely settled in the deflocculation tests.

There was a great tendency to warp and crack in drying. The malachite green test indicated that the clay was fine grained. The modulus of rupture of the clay-flint mixture was only moderate, being 492 lbs. per sq. inch.

The clay cylinders were 83.2% oxidized at the end of the oxidation firing.

The open porosity of the crude piece was less than 5% at cone 03 and there were no signs of overfiring until the temperature was above cone 12.

The open porosities of the washed sample followed closely that of the crude. The total porosities of the washed clay were somewhat lower than the crude.

The volume shrinkages of the crude and the washed clays were practically the same and overfiring was indicated in each instance at cone 14.

The true specific gravities of the crude and the washed clays fired at the different temperatures showed slight differences, but the latter clay gave a little higher values.

The apparent and the bulk specific gravities were practically the same at cone 2 and higher, which of course was expected from the agreement in porosities. The washed clay gave higher values than the crude. The volume shrinkage and the closed pore determinations agreed with the porosity determinations. The clay bars cracked a great deal in firing. This was more pronounced with the washed clay.

The color of the fired bars was a dark cream and the crude and the washed clay showed very little difference. Blue-stoning occurred at cone 7. Above cone 6 in the crude and cone 4 in the washed clay a brown stain was noticed on the surface of the test pieces.

Description of the Individual China Clays

China Clay VCI Sample No. 11 This clay was a typical kaolin. The plasticity was low and the dry clay bars were very weak; the modulus of rupture with the addition of 20% Tennessee ball clay No. 5 was only 134 lbs. per sq. inch.

This clay had the highest percentage porosities at all temperatures of any of the china clays tested.

China Clay AI Sample No. 12 This clay was of the same type as VCI. According to the malachite green test it appeared to be much finer grained. The plasticity and the modulus of rupture (148 lbs. per sq. inch) were slightly higher. The porosities at the different temperatures were quite typical of this kind of clay.

M&M China Clay Sample No. 13 This clay had in general the same characteristics as those above, excepting that the malachite green determination indicated a finer grain. The plasticity was fair and the mixture with 20% ball clay gave a modulus of rupture of 189 lbs. per sq. in.

The porosity at cone 14 was slightly lower than that of other clays of this type tested. The color of the fired pieces was excellent at all temperatures of firing.

Richardson's China Clay Sample No. 17 This clay approached very nearly to china clay VCI in its physical properties and firing behavior. However, it had a slightly higher strength[1] in the dry condition (148 lbs. per sq. in. modulus of rupture) and the porosity was a little less at cone 14.

M&M Imported China Clay Sample No. 19 This clay was in general very similar to Sample No. 13. The modulus of rupture[1] was slightly higher (210 lbs. per sq. in.) and the fineness as indicated by the malachite green test, less. The porosity at cone 14 was considerably greater than Sample No. 13 fired at the same temperature.

Georgia Kaolin,[2] Sample No. 15 This clay was typical of a high grade sedimentary kaolin. The plasticity was good and the malachite green determinations indicated that the clay was very fine grained. The modulus of rupture (with 20% ball clay) was 319 lbs. per sq. in.

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[1] Refers to the mixture containing 20% ball clay.

[2] From Dry Branch, Ga.

The firing curves were of the same type as those for the true china clays. The trial pieces fired at cones 03 and 01 after being soaked in water and dried showed a green discoloration. This was not noted at higher temperatures of firing.

Florida Kaolin,[1] Sample No. 16 This clay was typical of a high grade sedimentary kaolin. The clay was very plastic and had high shrinkage. With the addition of 20% Tennessee ball clay No. 5, the modulus of rupture reached 335 lbs. per sq. in., which was a higher value than that attained by the china clays.

The firing behavior approached that of an open firing ball clay rather than that of a true kaolin. Blue-stoning was noted with the trial pieces fired to cone 14. There was also a small amount of green stain present on the pieces fired at cones 01 to 03.

Comparison of the Kaolins The volume shrinkages of china clay VCI, china clay AI, MWM china clay, Richardson's china clay, M&M imported clay are all very similar in amount and rate, with a slight acceleration at cone 12.

The percentages of open pores at the different temperatures for the several clays mentioned are very similar and all show the same acceleration at cone 12.

The volume change of the Georgia kaolin and percentages of open pores are greater at each cone temperature, but the rate is approximately the same and there is the characteristic acceleration at cone 12.

The Florida kaolin shows much greater volume shrinkage and less porosity at all cone temperatures with a greater rate of change of porosity. There is, as with the other clays, a marked acceleration at cone 12.

Tables Tables I to X appear on the following pages, 621–28.

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[1] From Lake County, Fla.

TABLE I

Lab. No.	Clay	Water of plasticity	Vol. drying shrinkage	Shrinkage water	Pore water	Ratio pore water to shrinkage water	Bulk density of dried clay	Residue on 120-mesh	Modulus of rupture 1 clay – 1 flint lbs./ square inch	Malachite green adsorbed per gram of clay
1	Brown "Paragon" ball*	39.1	24.4	19.7	19.4	.98	1.67	1.52		
21	Brown "Paragon" ball	38.3	25.7	20.0	18.3	.91	1.76		685	.059
2	M&M ordinary ball*	42.6	24.7	20.4	22.3	1.10	1.61	1.22		
20	M&M ordinary ball	42.1	25.7	20.4	21.7	1.23	1.72		757	.059
3	Mo. Hercules*	30.3	18.3	12.7	17.6	1.38	1.76	6.12		
22	Mo. Hercules	31.8	20.3	14.3	17.5	1.22	1.81		538	.057
4	Ky. ball No. 8*	44.3	25.3	22.0	22.3	1.02	1.58	.23		
28	Ky. ball No. 8	44.6	25.9	22.6	22.0	.97	1.67		500	.059
5	Special Ky. ball*	49.4	26.5	24.8	24.6	.99	1.49	.63		
24	Special Ky. ball	54.8	30.3	28.8	26.0	.90	1.53		575	.059
6	Ky. ball No. 4*	46.5	29.0	24.4	22.0	.90	1.60	.17		
31	Ky. ball No. 4	46.0	26.8	22.5	23.5	1.05	1.66		530	.058
7	Dark "Paragon" ball*	40.0	21.2	17.3	12.1	.72	1.60	1.32		
27	Dark "Paragon" ball	43.3	26.1	21.6	21.7	1.00	1.66		819	.059
8	M&M ball*	34.2	21.9	16.1	18.1	1.19	1.72	.28		
30	M&M ball	35.7	24.5	18.0	17.7	.98	1.80		464	.059
9	M&M ivory fat*	30.6	22.2	15.5	15.0	.97	1.85	.11		
23	M&M ivory fat	31.0	22.7	15.1	15.9	.95	1.92		592	.058
10	S.G.P. ball*	40.2	20.6	17.2	23.0	1.33	1.54	.21		
26	S.G.P. ball	48.2	25.0	21.5	26.7	1.24	1.57		289	.054
14	Jernigan ball*	40.4	22.3	18.1	22.3	1.23	1.60	.06		
32	Jernigan ball	38.8	20.7	15.6	23.1	.66	1.69		284	.045
18	Dorset Eng. ball*	38.2	35.7	20.5	17.7	.86	1.77	.03		
33	Dorset Eng. ball	39.6	27.6	21.4	18.5	.85	1.82		744	.059
25	Eng. ball No. 25*	40.9	25.8	21.1	19.7	.93	1.71	.11		
29	Eng. ball No. 25	42.4	28.6	22.8	19.6	.85	1.80		492	.059
11	VCI china clay	39.7	14.8	12.1	27.6	2.76	1.45	.01	134	.015
12	AI china clay	38.9	18.	12.2	26.7	2.17	1.48	.05	142	.042
13	MWM china clay	39.4	16.7	13.5	25.8	1.91	1.49	.04	189	.045
15	Georgia kaolin	33.5	15.3	11.4	22.0	1.93	1.59	.11	319	.044
16	Florida kaolin	48.2	23.6	21.4	26.8	1.25	1.46	.13	335	.045
17	Richardson's china	38.4	13.3	10.4	28.0	2.80	1.45		148	.015
19	M&M imported china	39.4	16.9	13.6	25.8	1.89	1.50	.05	210	.028

* Crude clay, otherwise it is washed.

TABLE II

PERCENTAGE VOLUME FIRING SHRINKAGE

Lab. No.	Clay	Cone 03	Cone 01	Cone 2	Cone 4	Cone 6	Cone 8	Cone 10	Cone 12	Cone 14
1	Brown "Paragon" ball*	28.5	—	29.3	30.2	31.8	32.6	32.7	33.1	25.3
21	Brown "Paragon" ball		28.9	29.4	30.4	31.7	32.7	33.6	33.3	27.9
2	M&M ordinary black*	30.2	—	32.0	31.9	34.2	34.8	35.8	35.7	30.2
20	M&M ordinary black		31.5	32.4	32.9(*a*)	34.4	35.4	36.7	35.9	33.0
3	Mo. Hercules ball*	11.3	11.6	15.1	15.6(*a*)	17.1	18.8	19.2	20.4	26.0
22	Mo. Hercules ball		14.1	17.0	17.9	20.7	20.8	23.1	24.7	29.6
4	Ky. ball No. 8*	28.1	—	31.2	32.9(*a*)	33.6	35.8	38.5	39.7	40.8
28	Ky. ball No. 8		29.7	32.0	33.4(*a*)	35.7	36.7	40.2	40.9	41.5
5	Special Ky. ball*	28.8	—	31.4	33.3	34.7	37.1	39.3	40.1	41.0
24	Special Ky. ball		30.2	32.5	33.8(*a*)	37.4	38.5	41.4	42.5	43.5
6	Ky. ball No. 4*	28.2	—	31.3	33.0	34.2	36.4	37.9	40.3	42.5
31	Ky. ball No. 4		26.8	31.6	33.6(*a*)	34.9	36.7	38.7	39.4	42.2
7	Dark "Paragon" ball*	35.7	—	36.4	37.2(*a*)	38.9	40.0	41.2	41.5	44.2
27	Dark "Paragon" ball		36.5	37.6	39.0(*a*)	39.6	41.7	42.30	43.4	42.7
8	M&M ball*	25.7	—	27.3	27.6	29.7	30.3	32.1	31.7	22.0
30	M&M ball		26.3	28.3	29.1(*a*)	30.6	32.1	33.0	32.2	18.3
9	M&M ivory fat*	23.8	23.4	24.7	24.9	26.5	26.9	28.0	27.1	13.0
23	M&M ivory fat		24.7	25.8	26.6(*a*)	27.2	27.8	26.8	26.7	8.7
10	S.G.P. ball*	8.8	8.6	11.0	12.5	13.3	14.4	15.2	16.5	18.4
26	S.G.P. ball		24.4	32.5	34.1(*a*)	37.20	39.4	41.4	44.0	48.0
14	Jernigan ball*	19.1	20.3	22.2	24.7	27.6	34.8	38.9	36.8	32.5
32	Jernigan ball		20.9	22.6	24.2(*a*)	28.4	34.3	37.7	38.1	35.3
18	Dorset Eng. ball*	32.0	—	33.3	33.7(*a*)	34.1	33.6	34.1	34.3	28.3
33	Dorset Eng. ball		34.2	34.5	33.7(*a*)	35.3	34.2	33.6	34.7	31.
25	Eng. ball No. 25*	32.3	—	34.5	34.9(*a*)	36.4	34.6	36.1	35.9	29.0
29	Eng. ball No. 25		34.3	35.3	35.9	36.3	36.6	36.4	35.8	32.5
11	VCI china clay	11.0	—	12.3	14.4	17.7	20.0	23.0	23.8	34.0
12	AI china clay	10.0	—	14.0	15.0	20.4	20.3	25.2	25.0	35.4
13	MWM china clay	10.0	11.3	15.4	17.7	19.6	23.5	28.4	27.2	33.8
15	Georgia kaolin	13.1	13.7	16.4	19.7	24.1	28.6	29.6	30.3	38.1
16	Florida kaolin	17.8	19.8	21.3	30.0	33.7	38.2	38.7	41.6	49.0
17	Richardson china clay	9.2	10.3	13.3	16.3(*a*)	20.2	24.1	27.7	28.1	36.3
19	M&M imported china clay	9.5	11.0	14.0	18.3(*a*)	20.3	25.5	28.0	29.1	37.6

* Crude clay, otherwise it is washed.
(*a*) Pieces fired to cone 3.

TABLE III

PERCENTAGE APPARENT POROSITY

Lab. No.	Clay	Cone 03	Cone 01	Cone 2	Cone 4	Cone 6	Cone 8	Cone 10	Cone 12	Cone 14
1	Brown "Paragon" ball*	13.5	—	8.7	2.8	.4	.3	.1	.2	1.7
21	Brown "Paragon" ball	—	11.9	9.3	2.0(*a*)	.2	.1	.1	.1	.1
2	M&M ordinary black*	17.0	—	12.5	4.7	.5	.3	.2	.3	.4
20	M&M ordinary black	—	12.6	7.0	1.4(*a*)	.5	.1	.0	.0	.3
3	Mo. Hercules ball*	29.4	—	27.1	26.2	25.8	21.5	21.8	18.7	11.8
22	Mo. Hercules ball	—	30.6	29.1	26.1(*a*)	24.2	22.7	20.3	17.2	8.1
4	Ky. ball No. 8*	24.3	—	20.2	18.3	16.7	10.8	4.1	.2	.2
28	Ky. ball No. 8	—	21.4	19.8	16.9(*a*)	12.3	5.2	.5	.2	.3
5	Special Ky. ball*	26.1	—	24.1	21.4	19.7	11.2	1.1	.4	1.1
24	Special Ky. ball	—	28.5	25.7	24.1(*a*)	17.8	11.6	.0	.1	.1
6	Ky. ball No. 4*	24.4	—	20.5	19.0	17.0	10.9	6.5	.2	1.3
31	Ky. ball No. 4	—	25.9	21.3	17.6(*a*)	15.8	9.5	2.9	1.1	1.2
7	Dark "Paragon" ball*	16.0	15.8	15.7	12.0	6.8	1.3	.8	.7	2.4
27	Dark "Paragon" ball	—	15.4	13.5	9.7(*a*)	7.3	.1	.4	.8	.5
8	M&M ball*	16.7	—	12.1	10.3(*a*)	1.0	.6	.1	.1	1.9
30	M&M ball	—	13.9	10.3	6.5(*a*)	.3	.2	.0	.2	1.6
9	M&M ivory fat*	8.5	—	4.2	.9(*a*)	.6	.2	.4	.2	2.8
23	M&M ivory fat	—	3.6	2.5	.2(*a*)	.4	.1	.2	.1	2.1
10	S.G.P. ball*	31.3	—	26.7	22.7	20.4	17.3	13.8	9.9	1.7
26	S.G.P. ball	32.8	—	27.4	23.1(*a*)	19.2	15.9	11.4	5.4	1.1
14	Jernigan ball*	29.6	28.8	24.9	24.3	19.0	12.8	.3	.2	.1
32	Jernigan ball	—	20.9	22.6	24.2(*a*)	28.4	34.3	37.7	38.1	35.3
18	Dorset Eng. ball*	2.1	—	.2	.2	.2	1.9	.44	.5	1.7
33	Dorset Eng. ball	—	2.0	1.5	2.2(*a*)	.2	2.3	1.7	1.4	.5
25	Eng. ball No. 25*	4.7	—	2.1	1.5	.2	.5	.1	.2	1.1
29	Eng. ball No. 25	—	3.0	1.5	1.8(*a*)	1.1	1.2	.3	.2	.4
11	VCI china clay	43.7	—	42.8	41.4	38.9	38.8	36.2	35.1	24.5
12	AI Eng. china	42.9	41.3	41.3	38.0	39.7	35.0	33.2	30.3	18.6
13	MWM china clay	41.9	41.4	38.8	38.2	35.3	33.7	28.7	30.6	15.9
15	Georgia kaolin	39.2	38.1	37.9	34.8	32.2	27.6	26.4	25.1	15.1
16	Florida kaolin	40.3	39.9	41.1	32.5	29.2	23.5	22.3	18.6	3.2
17	Richardson's china clay	44.2	42.9	41.2	40.0(*a*)	35.3	31.6	29.2	26.4	19.2
19	M&M imported china clay	39.5	—	39.5	35.9(*a*)	35.5	31.3	28.7	27.2	18.7

* Crude, otherwise washed.
(*a*) Pieces fired to cone 3.

TABLE IV

TOTAL PER CENT POROSITY BASED ON BULK VOLUME OF PIECE

Lab. No.	Clay	Cone 03	Cone 2	Cone 6	Cone 10	Cone 12	Cone 14
1	Brown "Paragon" ball*	21.3	18.6	13.3	11.2	10.7	19.4
21	Brown "Paragon" ball		15.1	9.0	5.8	5.5	12.0
2	M&M ordinary ball*	25.6	21.1	14.5	11.9	11.9	15.4
20	M&M ordinary ball		13.7	9.4	6.7	6.3	9.9
3	Mo. Hercules ball*	36.5	32.0	30.4	27.3	26.1	19.1
22	Mo. Hercules ball		28.9	26.7	22.7	20.7	13.4
4	Ky. ball No. 8*	29.1	29.3	22.1	13.1	10.4	9.8
28	Ky. ball No. 8		21.1	15.7	6.1	5.0	4.7
5	Special Ky. ball*	35.0	32.9	29.1	19.2	17.9	11.7
24	Special Ky. ball		30.6	24.4	13.4	11.2	10.3
6	Ky. ball No. 4*	28.5	25.3	22.3	13.7	9.5	7.7
31	Ky. ball No. 4		22.4	18.4	8.9	6.1	4.5
7	Dark "Paragon" ball*	22.7	20.7	16.1	12.1	12.1	8.8
27	Dark "Paragon" ball		16.3	11.2	5.7	5.0	4.8
8	M&M ball*	21.1	17.4	12.6	7.9	7.9	17.8
30	M&M ball		14.3	7.3	4.1	4.2	18.2
9	M&M ivory fat*	13.5	11.1	6.9	5.1	5.0	19.0
23	M&M ivory fat		7.7	3.9	3.5	2.7	20.3
10	S.G.P. ball*	35.1	29.4	23.7	17.5	10.3	5.9
26	S.G.P. ball		26.1	20.2	12.4	8.7	2.1
14	Jernigan ball*	34.4	30.2	25.1	10.3	8.8	13.1
32	Jernigan ball		27.4	22.1	7.6	4.3	9.0
18	Dorset ball*	9.9	7.1	5.9	6.1	5.5	11.9
33	Dorset ball		3.6	2.3	4.7	2.6	6.0
25	Eng. ball No. 25*	11.9	8.4	6.9	5.0	5.3	12.9
29	Eng. ball No. 25		5.0	3.9	2.5	3.6	6.9
11	VCI china clay	47.3	45.5	42.0	39.4	38.9	29.9
12	AI china clay	47.1	43.9	41.6	36.1	35.9	25.9
13	M&M china clay	46.1	42.0	40.3	32.8	34.7	22.7
15	Georgia kaolin	41.4	39.3	34.1	29.4	28.3	19.6
16	Florida kaolin	44.0	41.5	30.3	25.7	21.9	8.7
17	Richardson's china clay	47.6	45.5	40.9	35.2	32.9	26.8
19	M&M imported china clay	47.5	43.4	39.4	33.5	32.6	23.3

TABLE V

BULK SPECIFIC GRAVITIES

Lab. No.	Clay	Cone 03	Cone 2	Cone 6	Cone 10	Cone 12	Cone 14
1	Brown "Paragon" ball*	2.06	2.07	2.15	2.20	2.19	1.96
21	Brown "Paragon" ball		2.18	2.24	2.31	2.31	2.12
2	M&M ordinary black*	1.96	2.04	2.11	2.16	2.16	2.08
20	M&M ordinary black		2.19	2.24	2.30	2.3	2.20
3	Mo. Hercules ball*	1.78	1.83	1.88	1.93	1.95	2.09
22	Mo. Hercules ball		1.90	1.98	2.05	2.08	2.22
4	Ky. ball No. 8*	1.91	1.99	2.08	2.22	2.27	2.31
28	Ky. ball No. 8		2.11	2.23	2.37	2.42	2.45
5	Special Ky. ball*	1.74	1.80	1.89	2.02	2.06	2.08
24	Special Ky. ball		1.86	2.01	2.14	2.18	2.23
6	Ky. ball No. 4*	1.92	2.01	2.09	2.21	2.30	2.39
31	Ky. ball No. 4		2.09	2.18	2.32	2.39	2.47
7	Dark "Paragon" ball*	2.06	2.07	2.17	2.26	2.26	2.35
27	Dark "Paragon" ball		2.21	2.29	2.41	2.43	2.43
8	M&M ball*	2.08	2.13	2.20	2.28	2.27	1.99
30	M&M ball		2.24	2.31	2.39	2.37	1.97
9	M&M ivory fat*	2.23	2.25	2.31	2.35	2.33	1.95
23	M&M ivory fat		2.35	2.40	2.40	2.39	1.92
10	S.G.P. ball*	1.76	1.91	2.06	2.21	2.30	2.49
26	S.G.P. ball		1.96	2.16	2.34	2.42	2.59
14	Jernigan ball*	1.76	1.88	2.01	2.30	2.30	2.16
32	Jernigan ball		1.95	2.09	2.37	2.41	2.26

* Crude clay, otherwise it is washed.

Table V (*concluded*)

Lab. No.	Clay	Cone 03	Cone 2	Cone 6	Cone 10	Cone 12	Cone 14
18	Dorset ball*	2.32	2.37	2.40	2.39	2.40	2.21
33	Dorset ball		2.48	2.51	2.44	2.49	2.37
25	Eng. ball No. 25*	2.26	2.32	2.32	2.39	2.37	2.15
29	Eng. ball No. 25		2.44	2.46	2.48	2.36	2.34
11	VCI china clay	1.41	1.45	1.54	1.65	1.66	1.91
12	AI china clay	1.41	1.50	1.57	1.73	1.73	2.01
13	MWM china clay	1.44	1.54	1.61	1.81	1.80	2.10
15	Georgia kaolin	1.59	1.64	1.80	1.94	1.97	2.20
16	Florida kaolin	1.51	1.58	1.90	2.03	2.13	2.45
17	Richardson's china clay	1.40	1.46	1.60	1.76	1.83	1.98
19	M&M imported china clay	1.40	1.52	1.64	1.81	1.83	2.08

* Crude clay, otherwise it is washed.

TABLE VI
TRUE SPECIFIC GRAVITIES

Lab. No.	Clay	Cone 03	Cone 2	Cone 6	Cone 10	Cone 12	Cone 14
1	Brown "Paragon" ball*	2.615	2.547	2.486	2.479	2.453	2.439
21	Brown "Paragon" ball		2.571	2.466	2.456	2.442	2.416
2	M&M ordinary black*	2.639	2.584	2.479	2.460	2.447	2.455
20	M&M ordinary black		2.535	2.471	2.467	2.454	2.447
3	Mo. Hercules ball*	2.681	2.686	2.698	2.649	2.644	2.588
22	Mo. Hercules ball		2.682	2.705	2.647	2.629	2.567
4	Ky. ball No. 8*	2.699	2.682	2.671	2.553	2.538	2.567
28	Ky. ball No. 8		2.677	2.648	2.527	2.548	2.573
5	Special Ky. ball*	2.686	2.679	2.662	2.507	2.506	2.506
24	Special Ky. ball		2.676	2.648	2.469	2.452	2.489
6	Ky. ball No. 4*	2.688	2.699	2.686	2.566	2.542	2.586
31	Ky. ball No. 4		2.690	2.679	2.541	2.515	2.587
7	Dark "Paragon" ball*	2.667	2.617	2.585	2.567	2.575	2.578
27	Dark "Paragon" ball		2.646	2.575	2.546	2.563	2.553
8	M&M ball*	2.638	2.585	2.521	2.478	2.456	2.416
30	M&M ball		2.619	2.497	2.493	2.475	2.405
9	M&M ivory fat*	2.583	2.537	2.484	2.476	2.454	2.413
23	M&M ivory fat		2.545	2.499	2.484	2.458	2.411
10	S.G.P. ball*	2.721	2.704	2.709	2.689	2.654	2.649
26	S.G.P. ball		2.700	2.708	2.672	2.651	2.650
14	Jernigan ball*	2.687	2.694	2.685	2.566	2.525	2.483
32	Jernigan ball		2.690	2.679	2.566	2.526	2.490
18	Dorset ball*	2.573	2.550	2.545	2.551	2.541	2.516
33	Dorset ball		2.572	2.561	2.565	2.551	2.517
25	Eng. ball No. 25*	2.562	2.531	2.497	2.518	2.514	2.465
29	Eng. ball No. 25		2.568	2.563	2.547	2.550	2.515
11	VCI china clay	2.673	2.665	2.701	2.717	2.716	2.722
12	AI china clay	2.677	2.679	2.693	2.708	2.709	2.713
13	MWM china clay	2.678	2.696	2.702	2.721	2.725	2.718
15	Georgia kaolin	2.707	2.705	2.721	2.744	2.744	2.740
16	Florida kaolin	2.707	2.706	2.722	2.739	2.740	2.686
17	Richardson's china	2.678	2.689	2.709	2.710	2.729	2.712
19	M&M imported china	2.672	2.686	2.704	2.720	2.720	2.718

* Crude clay, otherwise it is washed.

TABLE VII
APPARENT SPECIFIC GRAVITIES

Lab. No.	Clay	Cone 03	Cone 2	Cone 6	Cone 10	Cone 12	Cone 14
1	Brown "Paragon" ball*	2.38	2.28	2.17	2.20	2.19	2.00
21	Brown "Paragon" ball		2.41	2.25	2.32	2.32	2.12
2	M&M ordinary black*	2.40	2.32	2.12	2.17	2.18	2.08
20	M&M ordinary black		2.35	2.25	2.30	2.30	2.20
3	Mo. Hercules ball*	2.48	2.51	2.50	2.57	2.40	2.34
22	Mo. Hercules ball		2.66	2.62	2.58	2.52	2.42
4	Ky. ball No. 8*	2.52	2.50	2.49	2.31	2.28	2.32
28	Ky. ball No. 8		2.62	2.55	2.39	2.43	2.46

TABLE VII (*concluded*)

Lab. No	Clay	Cone 03	Cone 2	Cone 6	Cone 10	Cone 12	Cone 14
5	Special Ky. ball*	2.36	2.38	2.35	2.05	2.06	2.10
24	Special Ky. ball		2.52	2.43	2.14	2.18	2.22
6	Ky. ball No. 4*	2.52	2.53	2.52	2.37	2.31	2.42
31	Ky. ball No. 4		2.65	2.57	2.38	2.41	2.49
7	Dark "Paragon" ball*	2.45	2.49	2.33	2.27	2.30	2.40
27	Dark "Paragon" ball		2.55	2.38	2.40	2.46	2.43
8	M&M ball*	2.50	2.42	2.24	2.28	2.27	2.02
30	M&M ball		2.50	2.32	2.40	2.38	2.00
9	M&M ivory fat*	2.44	2.35	2.33	2.36	2.33	2.01
23	M&M ivory fat		2.52	2.42	2.41	2.40	1.95
10	S.G.P. ball*	2.57	2.60	2.60	2.57	2.54	2.51
26	S.G.P. ball		2.71	2.68	2.63	2.59	2.62
14	Jernigan ball*	2.44	2.51	2.48	2.31	2.31	2.16
32	Jernigan ball		2.59	2.61	2.40	2.41	2.27
18	Dorset ball*	2.35	2.37	2.40	2.39	2.42	2.28
33	Dorset ball		2.49	2.52	2.51	2.52	2.38
25	Eng. ball No. 25*	2.38	2.32	2.34	2.39	2.39	2.17
29	Eng. ball No. 25		2.46	2.49	2.49	2.49	2.35
11	VCI china clay	2.48	2.54	2.51	2.57	2.56	2.54
12	AI china clay	2.48	2.61	2.60	2.57	2.50	2.48
13	M&M china clay	2.50	2.51	2.49	2.52	2.56	2.50
15	Georgia kaolin	2.60	2.68	2.65	2.63	2.63	2.60
16	Florida kaolin	2.50	2.71	2.67	2.62	2.61	2.52
17	Richardson's china clay	2.52	2.48	2.47	2.49	2.49	2.45
19	M&M imported china clay	2.40	2.52	2.54	2.54	2.52	2.55

* Crude clay, otherwise it is washed.

TABLE VIII
CLOSED PORES (PER CENT)

Lab. No.	Clay	Cone 03	Cone 2	Cone 6	Cone 10	Cone 12	Cone 14
1	Brown "Paragon" ball*	8.9	10.5	12.8	11.1	10.7	18.0
21	Brown "Paragon" ball		6.3	8.6	5.7	5.2	12.0
2	M&M ordinary black*	9.1	10.4	13.5	11.9	10.7	15.3
20	M&M ordinary black		8.0	8.9	6.5	6.2	9.9
3	Mo. Hercules ball*	7.8	6.6	7.3	2.8	9.3	8.4
22	Mo. Hercules ball		2.5	3.1	2.3	4.0	5.6
4	Ky. ball No. 8*	6.7	6.7	6.5	9.7	10.0	9.6
28	Ky. ball No. 8		2.1	3.5	5.4	4.3	4.5
5	Special Ky. ball*	12.0	11.1	11.6	18.3	17.6	16.1
24	Special Ky. ball		6.5	8.1	13.2	11.0	10.5
6	Ky. ball No. 4*	6.3	6.1	5.8	7.8	9.3	5.5
31	Ky. ball No. 4		1.3	3.9	6.2	4.0	3.8
7	Dark "Paragon" ball*	8.0	5.0	9.6	11.6	10.7	6.8
27	Dark "Paragon" ball		3.5	7.5	5.7	4.2	4.9
8	M&M ball*	5.15	5.9	11.8	7.8	7.4	16.2
30	M&M ball		4.4	8.7	3.9	4.1	16.9
9	M&M ivory fat*	5.5	7.1	6.0	5.1	5.0	16.5
23	M&M ivory fat		1.0	3.25	2.9	2.4	17.9
10	S.G.P. ball*	5.5	3.7	4.5	4.3	4.1	5.0
26	S.G.P. ball		.0	1.2	1.6	2.4	0.9
14	Jernigan ball*	9.3	7.0	7.6	10.2	8.5	13.0
32	Jernigan ball		3.7	2.6	6.3	4.4	8.9
18	Dorset Eng. ball*	8.5	7.0	5.5	6.5	4.7	9.5
33	Dorset Eng. ball		3.3	1.7	2.0	1.2	5.3
25	Eng. ball No. 25*	7.2	8.5	6.05	4.7	4.8	12.0
29	Eng. ball No. 25		4.9	2.7	2.1	2.2	6.7
11	VCI china clay	7.1	4.7	7.1	5.5	5.6	6.7
12	AI china clay	6.9	2.5	3.3	4.8	7.5	9.1
13	M.W.M. china clay	6.6	6.8	7.8	6.2	6.2	8.0
15	Georgia kaolin	3.8	0.8	2.5	4.4	4.0	5.0
16	Florida kaolin	7.7	.0	1.8	4.2	4.6	6.0
17	Richardson's china clay	5.9	7.5	8.6	8.0	8.5	9.3
19	M&M imported china clay	10.1	6.3	6.1	6.7	7.2	5.9

* Crude clays, otherwise it is washed.

TABLE IX
COLOR OF FIRED BRIQUETTES

Clay No.	Cone 03	Cone 01	Cone 2	Cones 3 and 4	Cone 6	Cones 6¾–7	Cone 8	Cone 10	Cone 12	Cone 14
1	−c	−c	−c	+c	+c	+c	+c	+c	−B	+B
2	"	"	"	"	"	"	"	"	"	"
3	w	w	w	w	w	w	−c	−c	−c	c iron spots
4	w	−c	−c	−c	−c	−c	−c	−B	++B	++B
5	w	w	"	"	"	"	−B	−B	+B	++B
6	w	w	w	w	−c	−c	−B	−B	++B	++B
7	−c	−c	+c	+c	+c	+c	+c	−B	+B	+B
8	+c	+c	++c	++c	++c	++c	++c	++c	+B	w−B
9	+c	+c	++c	++c	++c	++c	++c	++c	−B	w−B
10	w	w	−c	−c	−c	−c	−c	+c	+c	++B
11		w	w	w	w	w	w	w	w	w
12		"	"	"	"	"	"	"	"	"
13	w	"	"	"	"	"	"	"	"	"
14	w	w	−c	−c	+c	+c	++c	+B	+B	+B
15		w	w	w	w	w	w	w	w	w
16		w	w	w	w	w	w	w	w	++B
17		w	w	w	w	w	w	w	w	w
18	++c	++c	++c	++c	++c	++c	++c	−B	+B	+B
19		w	w	w	w	w	w	w	w	w
20		−c	+c	+c	+c	+c	+c	−c	−c	w
21		+c	+c	+c	+c	+c	+c	+c	−B	−B
22		w	w	w	w	w	w	w	w	−B
23		+c	+c	++c	++c	++c	++c	++c	++c	−B
24		w	−c	+c	+c	+c	+c	+c	−B	−B
25	+c	+c	++c	++c	++c	BG	−B	−B	+B	+B
26		w	w	w	−c	−c	−c	−c	−c	++B
27		−c	−c	−c	−c	−c	−c	−B	−B	−B
28		−c	−c	−c	−c	+c	+c	−B	−B	+B
29		++c	++c	++c	++c	−B	−B	+B	+B	−B
30		w	−c	−c	+c	+c	+c	++c	++c	−c
31		w	w	w	w	w	w	−c	+B	−B
32		w	w	−c	−c	−	c	+B	+B	+B
33		c	c	−BG	+BG	+BG	+BG	+B	+B	+B

White = w Cream = c Brownish gray = BG Blue stone = B Light − Moderate + Decided ++

TABLE X

STAINS ON BRIQUETTES AFTER FIRING

Clay No.	Cone 03	Cone 01	Cone 2	Cones 3 and 4	Cone 6	Cones 6¼–7	Cone 8	Cone 10	Cone 12	Cone 14
1	–	–	–	–	–	–	–	–	–	–
2	+G	+G	–	–	–	–	–	–	–	–
3	+G	–G	–	–	–G	–	–	–	–	–
4	+++G	++G	+G	–G	–G	–B	–B	–	–B	–B
5	+++G	++G	–G	–	–G	–	–	–	–	–
6	+++G	++G	+G	–	+G	–G	–	–	–	–
7	–	–	–	–	–B	–B	++B	+B	–B	–B
8	–G	–	–	–	–	–	–	–	–	–
9	–	–	–	–	–	–	–	–	–	–
10	+++G	++G	++G	+G	++G	++G	++G	–	–	–
11	–	–	–	–	–	–	–	–	–	–
12	–	–	–	–	–	–	–	–	–	–
13	–	–	–	–	–	–	–	–	–	–
14	+++G	++G	–B	–	+B	++B	++B	++B	++B	++B
15	+G	+G	–	–	–G	–G	–	–G	–G	–
16	+G	–G	–	–	–B	–G	–	++G	–G	–
17		–	–	–	–	–	–	–	–	–
18		–	–	–	–	–	–	–	–	–
19		–	–	–	–	–	–	–	–	–
20		–	–	–	–	–	–	–	–	–
21		–	–	–	–	–	–	–	–	–
22		–G	–G	–	–	–G	–	–	+B	–
23		–	–	–	–	–	–	–	–	–
24		++G	++G	–B	–G	–G	–	–	–	–
25	–	–	–	–	–	–B	+B	+B	+B	–
26		+G	+G	+G	+G	+G	–G	–G	–	–
27		+G	–	–	–B	–B	+B	+B	+B	–B
28		–G	–G	–	–	–	–	–	–	–
29		–	–	–	–B	–B	–B	–B	–B	–
30		–	–	–	–	–	–	–	–	–
31		–G	–G	–G	–G	–G	–	–	–	–
32		–	–B	–	–G	–	–	–	–	–
33	–	–	–	–	–	–	–	–	–	–

Green stain = G
Brown stain = B

Slight	–
Considerable	+
Large amt.	++
Excessive	+++

SERVICE FACTORS GOVERNING THE SLAGGING OF BOILER-FURNACE REFRACTORIES[1]

By R. A. Sherman[2] and Edmund Taylor[3]

ABSTRACT

Service factors, dependent on the type of coal burned and the method of burning, that are considered to govern slag erosion directly are: refractories temperatures, furnace gas temperatures, furnace gas compositions, furnace gas velocities, slag composition, and slag quantities. Values determined for part or all of these factors under each of the following sets of conditions are presented and their significance is discussed: eastern bituminous coals on underfeed stokers, powdered eastern bituminous coals in furnaces with extended radiant-heat absorbing surface, high-sulphur Pittsburgh coal on underfeed stokers, low-sulphur Pittsburgh coal on underfeed stokers, high-sulphur Pittsburgh coal on chain-grate stokers, Illinois coal on chain-grate stokers, and powdered Illinois coal.

Introduction

One of the most serious causes of failure of refractories in boiler furnaces fired with coal is the erosion by slag from the coal ash. The total expense incident to this and other types of failure has become so great that there has been a marked tendency in the past two years to protect or entirely replace by water or steam-cooled surfaces the refractories in the areas most seriously affected. Some boilers have no refractories within the furnace.

The factors governing slag erosion may be divided into two classes:

1. Service factors, dependent on the type of coal burned and the method of burning.

2. Refractories factors, dependent on the type of clay used and the method of manufacture.

The purpose of this paper is to deal with the first class of factors, discussing their significance and presenting values obtained in the field investigation of refractories service conditions conducted by the U. S. Bureau of Mines in coöperation with the Special Research Committee on Boiler Furnace Refractories of the American Society of Mechanical Engineers.

The main objective of this investigation is to supply information to the ceramic engineer to aid him in the study of the mechanism of slag erosion, spalling, and other causes of failure, and enable him to designate the proper application of the present refractories, or point to the development of special refractories.

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The investigation of the second class of factors is being conducted concurrently by the Bureau of Standards in coöperation with the Bureau of Mines and the A. S. M. E. Committee.

Scope of Investigation

The service factors that are considered to govern slag erosion directly and are being experimentally investigated in the field for various coals and coal burning equipment are: (1) refractories temperatures, (2) furnace gas temperatures, (3) furnace gas composition, (4) furnace gas velocities, (5) slag composition, and (6) slag quantities.

At this time, values for part or all of these factors have been determined under each of the following sets of conditions: (1) eastern bituminous coals on underfeed stokers, (2) powdered eastern bituminous coals in furnaces with extended radiant-heat absorbing surface, (3) high-sulphur Pittsburgh coal on underfeed stokers, (4) low-sulphur Pittsburgh coal on underfeed stokers, (5) high-sulphur Pittsburgh coal on chain-grate stokers, (6) Illinois coal on chain-grate stokers, and (7) powdered Illinois coal.

Refractories Temperatures

It is entirely obvious that the temperature of the hot surface of the refractory wall and the gradient through the wall are of importance in slag erosion. If the surface of the brick is somewhat softened, the molten ash deposited on it adheres and combines much more readily than if the surface were hard.

The temperature gradient through the brick determines the depth of absorption of slag, if any, as this will stop at the plane where the temperature is sufficiently low to cause congealing of the slag.

The maximum surface temperatures of refractories measured in the furnaces investigated ranged from 2500°F[1] in the walls of an underfeed stoker-fired furnace to between 2700 and 2800° in the arch of a furnace burning Illinois coal on a forced-draft chain-grate stoker and in the side wall of a powdered coal furnace.

These temperatures were well below the softening temperatures of the refractories as ordinarily determined, but were above the softening temperatures and frequently above the fluid or free-running temperatures of the coal ash.

Furnace Gas Temperatures

The temperature of the furnace gases often determines the temperature reached by the walls, although the temperature of the fuel

[1] Fahrenheit scale used throughout this paper.

bed, by radiation to the walls, may be the more important determining factor. The gas temperature also governs the temperature, and hence the plastic state of the ash carried in the gases to be deposited on the walls.

It is frequently found that the temperature of the gases within 4 to 6 inches of a furnace wall is lower than that of the gases within the furnace. This may be caused by air infiltration through the wall or past the ledge plate or side tuyeres of the stoker. It is also frequently true that the temperature of the gases next to the wall is lower than that of the wall. In such case the temperature of the wall is determined by radiation from the higher temperature fuel bed or the main body of furnace gases.

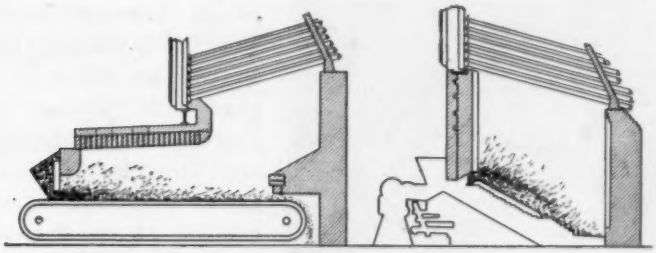

FIG. 1.—Sectional elevation of underfeed stoker on right, and chain grate stoker on left, showing relation to the boiler tubes.

Gas temperatures of 2750° have been measured in the underfeed stoker furnaces studied, but normally the maximum temperatures measured did not exceed 2600°. The maximum gas temperatures measured in chain-grate stoker and powdered coal furnaces were from 2700 to 2800°.

The difference in the gas temperatures in underfeed and chain-grate stoker furnaces is accounted for by the difference in the type of construction. Figure 1 shows the typical construction of these two types of furnaces. The chain-grate is set under an arch making a "dutch oven" with little of the furnace open to radiation to the boiler tubes, while the underfeed stoker is rarely set under an arch and the entire area of the fuel bed and furnace may radiate to the tubes.

Although the flame in a powdered coal furnace is generally "in sight of" the boiler tubes and frequently of additional heat-absorbing surface in the walls or bottom of the furnace, the temperatures may be relatively high because of a low excess of air or frequently because the zone of intense combustion is confined to a small part of the furnace which may be shielded from radiating to the heat absorbing surface.

Furnace Gas Composition

The most important item in the composition of the furnace gases with relation to slagging is the content of reducing gases: carbon monoxide and hydrogen. The most generally accepted explanation of the greater slagging in the presence of these gases is the reduction of the ferric to ferrous iron and the consequent formation of ferrous silicates, which melt at a lower temperature than ferric silicates.

Operation of Underfeed Stoker

Figure 2 shows the interior of an underfeed stoker-fired furnace. Coal is fed from the hopper by rams which push it up through the incandescent fuel bed. Between the retorts into which the coal is fed are the windboxes from which air is supplied under pressure through cast-iron tuyere plates. The coal thus forms a series of peaks and valleys from side to side of the furnace, the secondary air necessary for the combustion of the volatile matter, carbon monoxide, and hydrogen arising from the fuel bed comes through the valleys, and cracks formed by the shrinkage of the caked coal. The bed varies in thickness from 6 to 10 inches above the tuyeres at the front to a maximum of 18 to 36 inches at the thickest part, approximately halfway to the rear of the furnace and then decreases in thickness to the dump-plates or clinker grinders where the ash is discharged into the ash pit. In the latter part of the coal travel the stoker is partly overfeed in operation.

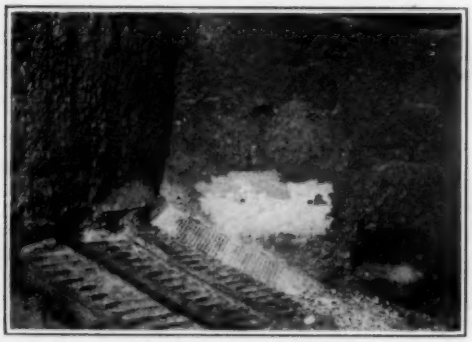

FIG. 2.—Interior of underfeed stoker-fired furnace showing method of supplying coal and air.

The great depth of the fuel bed is favorable to the presence of reducing gases directly above it and considerable quantities (12 to 14% of carbon monoxide has been found) occur along the front wall and along the side wall over the thickest part of the bed.

These stokers were originally used principally for coking coals. Hence the higher grade eastern bituminous coals are generally burned on them, although they have been adapted to the free-burning such as Illinois coals, with considerable success. Slag erosion is not, therefore, generally the most serious refractories problem with these stokers, although deep cuplike erosion occurs on the front wall above the

tuyeres in many installations. The reducing content of the gases is generally greater over the tuyeres although this is not invariably true.

Effect of Slag Adhesion

The adhesion of slag to the walls is the more frequent problem with these stokers, owing to the class of fuel burned on them, and the relatively moderate temperatures, and ventilated blocks are frequently installed up to the top of the fuel bed on the front, side, and bridge walls to lessen the adhesion by cooling the wall and maintaining an oxidizing atmosphere. Figure 3 shows the comparative gas temperatures and excess air above the fuel bed of an underfeed stoker burning

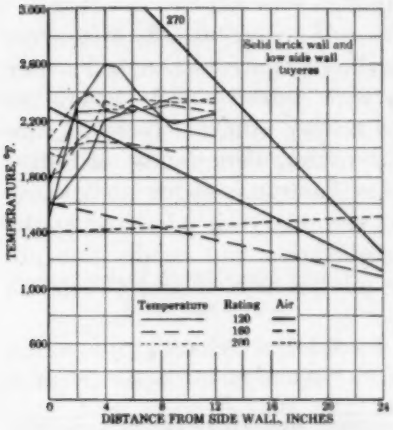

FIG. 3*a*.

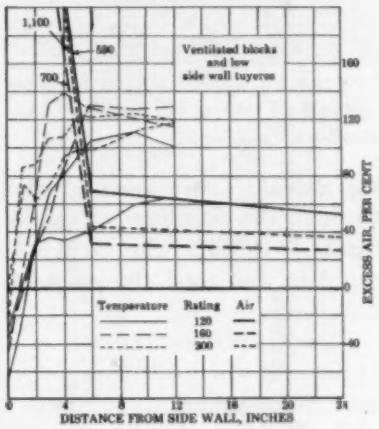

FIG. 3*b*.

Gas temperature and composition at side wall, underfeed stoker furnace.

a Pocahontas coal with solid brick walls and with ventilated refractory blocks. The excess air directly inside the wall is much higher with the ventilated blocks, but the effect did not extend beyond approximately six inches from the wall. The gas temperatures show the same condition; the temperatures ranged from 1600 to 2000° inside the solid wall and from 400 to 1000° inside the ventilated wall, but at four to six inches from the wall the temperatures were approximately the same with either installation. The slag adhesion was less during the period of observation with the ventilated blocks and the general experience of others has been that they are helpful if care is taken to keep the holes free from slag.

Operation of Chain-Grate Stoker

Coal is fed into chain-grate stoker furnaces from the hopper by the continuous movement of the grate in an even layer, varying from four

to seven inches, adjusted by the height of the coal gate. The latter figure is not often exceeded in present practice. The coal passes under an ignition arch which serves to reflect heat from the hotter part of the fuel bed onto the green coal. The depth of the fuel bed decreases naturally through the length of the grate. When air is supplied by forced draft, the windbox is generally divided into compartments with dampers so that the air supplied to the distillation and other zones of the grate may be controlled.

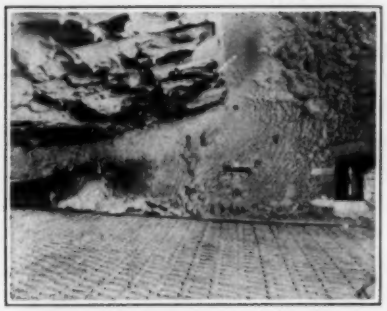

FIG. 4.—Interior of chain grate stoker-fired furnace showing slag erosion on side wall.

There is a zone, usually 2 to 3 feet from the coal gate, although this may vary with different coals, where the gases arising from the fuel bed contain considerable amounts of reducing gases. These are burned when they meet the excess air coming through the rear part of the bed or by secondary air admitted at the front or through the arch. As the gasification and combustion are rapid in this zone the gases generally fill the furnace and sweep the side walls.

Figure 4 shows the side wall of a forced-draft chain-grate stoker furnace on which Pittsburgh coal had been burned for 367 service hours from the installation of a new wall. There is a deep pocket-like erosion starting at about twenty inches from the front of the furnace which extends to the back, increasing in width but decreasing in depth. The temperature of the most deeply eroded area was not as high as of areas which were eroded less, but the gases contained up to 12% carbon monoxide and 5% hydrogen, and were greatest at about 150% of boiler rating.

FIG. 5.—Interior of chain-grate stoker-fired furnace showing reduction of slag erosion on side wall.

It was conceived that the admission of air to reach this area might eliminate the reducing gases next to the wall and reduce the erosion. A pipe was installed through the side wall at the nose of the ignition arch which pointed toward

the eroded area, and this pipe was connected to the air duct and the air supply was increased by means of a steam injector. It was found that the reducing gases could be entirely eliminated and the gas temperatures were reduced from 200 to 300° at the point of sampling. The furnace was operated for a period of about three weeks after building a new wall in this area, with air admitted during all steaming periods.

Figure 5 shows the wall at the end of this time. The erosion was not entirely eliminated but was reduced in area as can be clearly seen from the nearly horizontal upper limit of the eroded area.

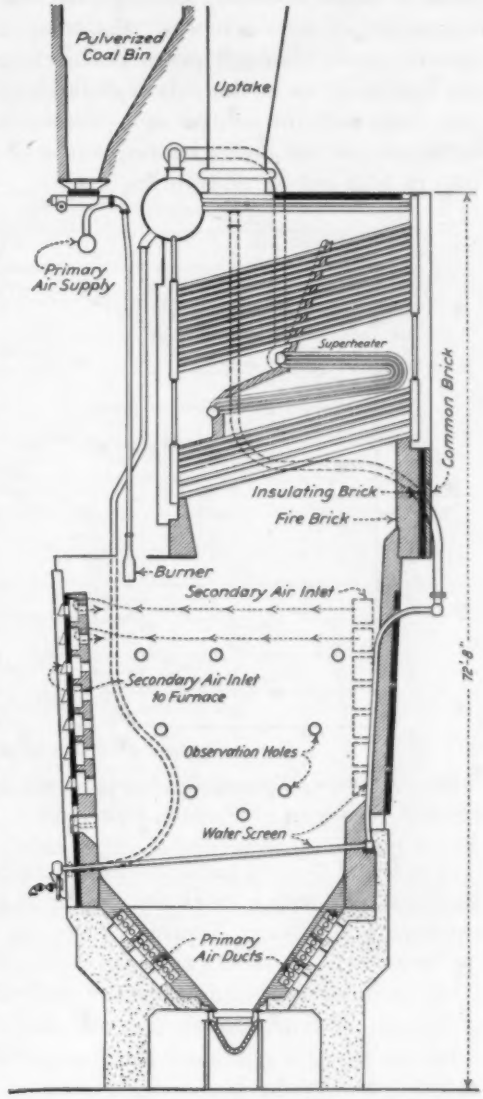

FIG. 6.—Sectional elevation of powdered coal furnace showing position for sampling gases and measuring temperatures.

Operation of Powdered Coal Furnace

The powdered coal method of firing differs in principle from those of hand firing or stokers in that all the coal, and consequently all the coal ash, is carried in suspension in the gases. In stoker firing the ash carried in the gases varies with the rate of burning and depends somewhat on the fineness and caking qualities of the coal; the maximum amount may be about 20% of the ash in the coal.

The possibility exists that the refractories in a powdered coal furnace may be bombarded with a greater weight of ash or slag particles, although these may be smaller than those arising from the fuel beds. It is therefore desirable to keep the furnace gases from impinging onto refractory surfaces.

Figure 6 is a sectional elevation through a powdered coal furnace in which the coal from a storage bin with about 15% of air, heated by passing through ducts in the ash pit lining, necessary for its combustion is fed vertically through flat burners whose longest dimension is parallel to the side wall; the remainder of the air is supplied by natural draft through ports in the front wall after passing through horizontal lanes in the side wall back of the 9-inch brick lining. The rear wall and the ash pit are protected by water-screen tubes which form part of the boiler heating surface. The side and front walls and burner arch are of refractories.

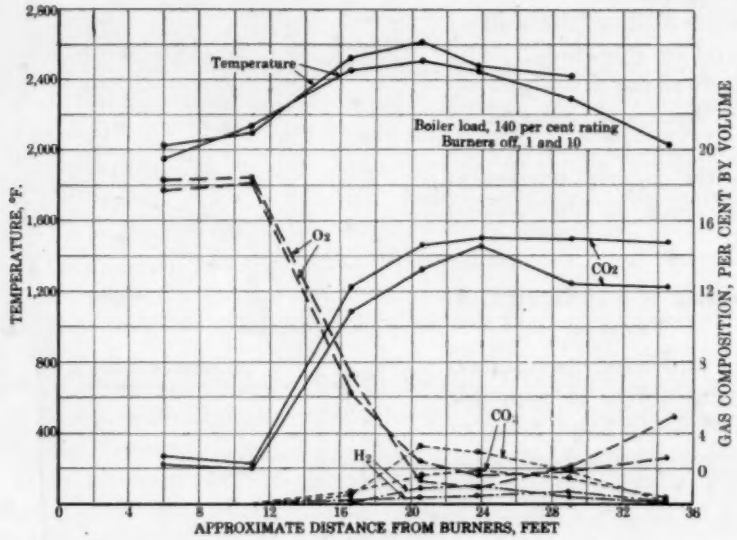

FIG. 7*a*.—Furnace gas temperature at six inches; gas composition at four inches from side wall. Powdered coal furnace, Illinois coal.

The flame takes a path downward and then upward in a U as shown by the circles which mark the positions at which gas temperatures and samples were taken. Figure 7 shows the temperature and composition of the gases at six inches and four inches from the side wall, respectively, when burning an Illinois coal at three boiler loads of 140, 190, and 240% of rating. The maximum gas temperatures occurred at about 22 feet from the burners and were 2600° at 140% and 2760° at 190 and 240% rating.

The CO_2 content was low and the oxygen content high at the first two sampling positions, 6 feet and 11 feet from the burners, because the flame did not reach the side wall there, but the CO_2 content inincreased rapidly and CO and H_2 were found at the three lower

positions in the furnace, increasing from 2 to 3% at 140% rating to 4% at 190% rating, and to 8 and 12% at 240% rating.

Figure 8 shows the side wall of this furnace 4 weeks after rebuilding the lower part of the wall. There was approximately 2 inches erosion in the area above the water-tube slag screen where the gas temperatures and reducing content were at a maximum. Figure 9 shows a wall which has been carried to complete failure and shows more clearly the coincidence of the eroded area and the area of high temperatures and high reducing gas content. The deleterious effect of the reducing

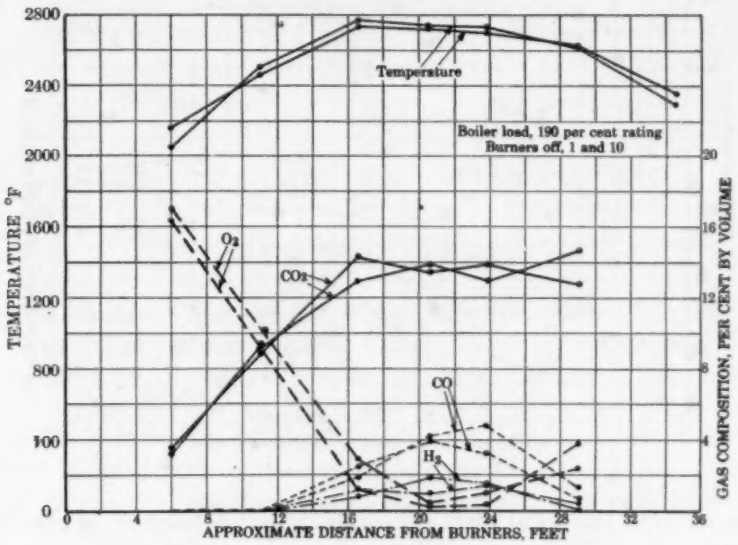

FIG. 7*b*.

gases can not be doubted and if they were eliminated the erosion would most probably be lessened.

The sulphur content of the furnace gases at the walls is also being determined at various locations of each furnace investigated. It adds to the general information, but there are no data at present on the relation of SO_2 or SO_3 in gases to the slagging or other failure of refractories.

Furnace Gas Velocities

The velocity of the gases in the furnace determines first the carrying power of the gases for solids; second, the amount carried in unit time; and, third, the tendency to sweep the molten combination away to expose fresh surface for attack.

The velocities at the furnace wall in chain-grate stoker furnaces reached forty feet a second at the nose of the main arch. When it is considered that this is equivalent to about twenty-seven miles an hour

it is seen that the gases possess a considerable carrying power for finely divided solids.

The velocities in underfeed stoker-fired furnaces are much more irregular on account of the changing condition of the fuel bed. The mean velocities over any one refractory wall are lower than in the chain-grate furnace owing to the fact that the gases are not confined

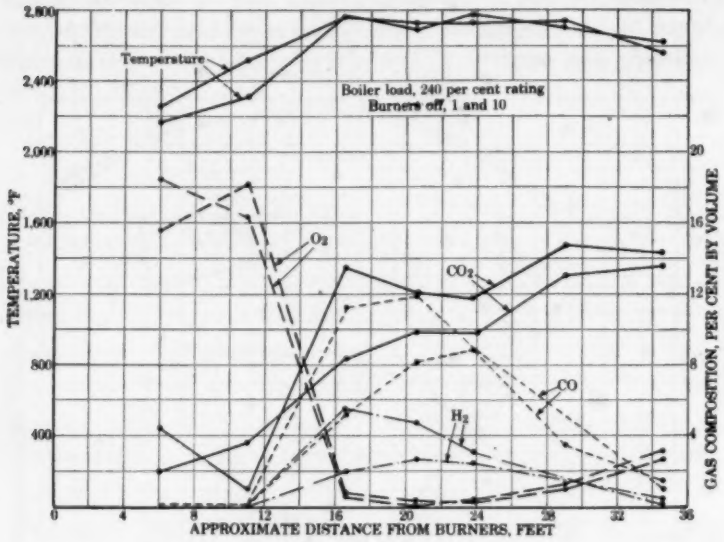

FIG. 7c.

under an arch but local high velocities do occur because of cracks in the fuel bed. Values of forty-five feet a second have been measured.

The entrance velocities of the coal and air into the powdered coal furnace as described above are very high, but the velocity is quickly dissipated in the relatively large furnace volume. The maximum velocity measured at the side wall of this furnace was about twenty feet a second.

Slag Composition

One of the most frequently considered and obviously important factors governing slag erosion is the composition of the coal ash fired to the furnace. Table I gives the composition of the ashes of a Pocahontas coal, two Pittsburgh coals, and two Illinois coals, burned in furnaces studied in this investigation. These are not considered representative of the fields from which they come but are given to illustrate the variations in coal ash composition.[1]

[1] See also "Fusibility of Coal Ash as Related to Clinker Formation," by W. A. Selvig, P. Nicholls, W. L. Gardner, W. E. Muntz, and E. B. Ricketts, Carnegie Inst. of Tech., *Bull.*, No. 29 (1927), pp. 5, 7, 16, 17, 23, 51.

The Pocahontas coal has a low Fe_2O_3 content as well as other fluxes and, though its softening temperature is not exceptionally high, would not be expected to present serious difficulty from slagging. The Pittsburgh coal No. 1 with its low Fe_2O_3 content and high softening temperature is an ash which would also be expected to give little slag erosion, while No. 2 with its high Fe_2O_3 content and low softening temperature promises considerable difficulty from slagging.

TABLE I

COMPOSITION OF COAL ASHES

Composition (per cent)	Pocahontas coal	Pittsburgh coal		Illinois coal	
		1	2	1	2
SiO_2	53.2	55.9	45.6	54.2	41.5
Al_2O_3	27.9	29.7	22.1	25.6	13.4
Fe_2O_3	9.7	8.3	26.3	10.1	14.3
CaO	2.9	2.0	1.7	3.2	14.6
MgO	1.8	0.6	0.8	1.1	0.9
Na_2O, K_2O (by difference)	—	2.3	2.2	2.8	2.9
Sulphur as SO_3	—	1.2	1.3	3.0	12.4
Softening temp., °F	2345	2650	2100	2390	2040
Ash in coal	6.0	9.3	10.7	13.6	16.3

Figure 10 shows the interior of an underfeed stoker-fired furnace after a period of burning the No. 1 coal. The heavy accumulation of slag on the walls will be noted. Figure 11 shows the same furnace after a like period of burning the No. 2 coal. The walls were cleaned of slag; only a thin coating remained on the bricks except at the surface of the fuel bed. Considerable erosion had taken place.

The Illinois coal ash No. 1 is really excellent for a coal from that field. It compares favorably with the Pocahontas coal ash. The ash of the No. 2 Illinois coal is extremely interesting owing to the exceptionally high lime content. A furnace burning coal of this type in powdered form is now being investigated. This coal is being burned with apparent success and the station reports satisfactory refractory maintenance costs under operating conditions of high boiler ratings.

Composition of Coal Ash and Slag

One of the early findings in this investigation was that the composition of the coal ash fired to the furnace and of the slag carried in the gases to be deposited on the walls differed. Samples of slag were taken from the first row of boiler tubes over a forced draft chain-grate stoker burning Illinois coal. The composition of two samples of the ash of this coal and the composition of the material next to the boiler tubes and of the outer portion is given in the first part of Table II. The inner material was light in color and unfused, while the outer portion was dark and glassy. Whereas the coal ash contained approxi-

mately 19% of Fe_2O_3 the slags contained more than 23%. The material next to the tubes contained a total of 8.5% alkalis while that on the outside contained only 3.4%. The SO_3 content was also considerably higher next to the comparatively cool surface of the tubes.

The second section of Table II contains the analyses of samples of coal ash and slags from a furnace burning Pittsburgh coal on a forced-draft chain-grate stoker. This coal ash is notable for its high Fe_2O_3 content. The samples of slags from the furnace gases were taken into a water-cooled sampler directly from the gases and were thus quickly cooled, and should represent the composition of the material in the gases more accurately than does the material on the boiler tubes which remains in contact with the hot gases. The Fe_2O_3 content of this material also is considerably greater than that of the coal ash. The sample of slag taken from the boiler tubes of this furnace shows an even greater increase in Fe_2O_3 content. The Fe_2O_3 content of the ash and refuse from the ash pit is less than that of the coal ash fired to the furnace, and calculation by weighing the compositions according to the fractions carried in the gases and to the ash pit showed that the increase in Fe_2O_3 in the material in the gases was balanced by its decrease in the ash and refuse.

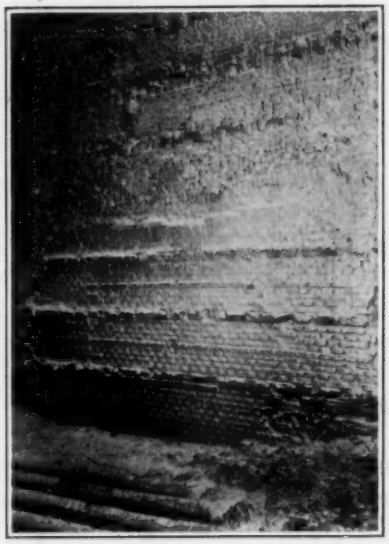

FIG. 8.—Side wall of powdered coal furnace showing erosion.

The third and fourth sections of Table II give the composition of samples of coal ash and slag obtained when burning a low and a high-sulphur Pittsburgh coal on an underfeed stoker. The analyses of the material from the gases are only approximate because of the small quantities which were obtained. These samples show, however, the same tendency previously noted, concentration of the iron in the material carried up from the fuel bed by the gases. The last two samples again show the deposition of the alkalis on the cool surface of the boiler tubes.

The last item of each sample gives the silica-alumina ratio. In each group except the first there is a decrease in this value for the material taken from the gases from its value for the coal ash, while it remains constant for the ash and refuse. The exact cause and signifi-

cance of this change remains to be determined by the ceramic laboratory investigators.

No analyses have been received at this time of the material taken from the gases of the powdered coal furnace investigated. While it appears improbable that there could be a change in the composition when all of the ash is carried in the gases as it is in these furnaces, no prediction can be safely made.

TABLE II
COMPOSITION OF COAL ASH AND SLAG SAMPLES

Item	Coal Burning Equipment	Description of Sample	Composition (per cent)									
			SiO_2	Al_2O_3*	Fe_2O_3	FeO	CaO	MgO	K_2O	Na_2O	SO_3	SiO_2/Al_2O_3 ratio
		Illinois coal ash	46.5	20.4	19.8	—	5.1	0.6	3.6†		4.0	2.28
		Illinois coal ash	43.5	18.1	18.0	—	8.1	0.5	3.2†		8.6	2.40
1	Forced draft chain grates	Slag from boiler tubes Material next to tubes	33.2	16.5	23.7	1.7	5.6	0.7	4.6	3.9	6.6	2.00
		Slag from boiler tubes Material on outside of pieces	40.5	17.3	22.7	7.3	6.8	1.0	1.9	1.5	0.2	2.30
		Pittsburgh coal ash	42.3	20.7	29.2	—	2.8	0.7	2.8†		1.5	2.04
2	Forced draft chain grates	Slags from furnace gases	33.7	18.5	34.9	—	3.5	0.7	0.6†		3.5	1.82
		Slag from boiler tubes	29.6	17.1	46.2	2.9	1.8	0.4	1.8†		0.2	1.73
		Ash and refuse from ash pit	46.2	21.6	27.6	—	2.5	0.6	1.1†		0.4	2.10
		Pittsburgh coal ash	55.9	29.7	8.3	—	2.0	0.6	2.3†		1.2	1.88
3	Underfeed stoker	Slags from furnace gases‡	46.2	30.6	10.1	—	1.8	0.1	—		0.6	1.51
		Ash and refuse from ash pit	57.9	30.5	7.9	—	1.3	0.5	1.8†		0.1	1.90
		Pittsburgh coal ash	45.6	22.1	26.3	—	1.7	0.8	2.2†		1.3	2.06
		Slags from furnace gases‡	39.4	21.3	32.6	—	1.3	0.6	—		0.1	1.85
4	Underfeed stoker	Ash and refuse from ash pit	48.0	23.3	23.3	—	1.8	1.0	2.0†		0.6	2.06
		Slag from boiler tubes, inner portion	—	—	—	—	—	—	3.9	2.0	—	—
		Slag from boiler tubes, outer portion	40.3	22.6	33.5	—	1.9	0.5	1.0†		0.2	1.78

* Al_2O_3 contains any TiO_2. † Alkalis, by difference. ‡ Approximate composition, insufficient sample for accurate analysis.

Slag Quantities

A frequent and entirely logical method of designing a slag test for refractories is that of introducing powdered ash or slag into a flame to be sprayed on the bricks under test. Investigators have lacked any information on the quantities of material which are carried per unit volume of gas under service conditions and have had to choose an arbitrary value.

FIG. 9.—Side wall of powdered coal furnace showing area of maximum erosion.

An attempt has been made in this investigation to supply this information. A method of sampling has been developed wherein the gases with their accompanying solids are drawn into a water-cooled tube placed in the furnace with the open end facing the direction of gas flow. The rate of flow is set so that the

linear velocity of entrance of the gases into the sampler is approximately that of the gases at the point. A part of the solids is deposited in the tube and the remainder is collected in a cyclone type separator and filter on the outer end. The volume of gases taken through the sampler is measured and the weight of solids per unit volume is thus obtained.

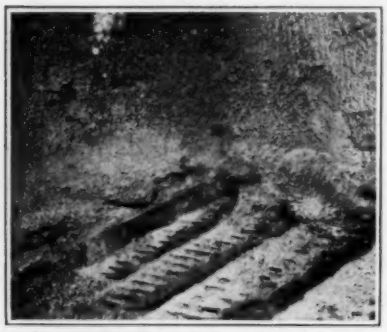

FIG. 10.—Interior of underfeed stoker-fired furnace after burning low sulphur Pittsburgh coal.

As the volume of gases sampled was necessarily low, and as the velocity of the gases at a given point does not remain constant from minute to minute, the values can be considered only approximate, but it is believed that they are a fair approximation.

The weight of ash per 100 cubic feet of gas in the chain-grate stoker-fired furnace burning Pittsburgh coal at a point next to the wall, and halfway between the grate and the nose of the arch, was 2 grams at 150% of boiler rating. The amount in the gases at 18 to 24 inches from the wall at the same position varied from 3 grams at 130% rating to 6 grams per 100 cubic feet at 190% rating.

The quantity of ash or slag in the gases of an underfeed stoker-fired furnace varied from 0.2 grams at 133% rating to 1.3 grams per 100 cubic feet at 180% rating when burning a low-sulphur Pittsburgh coal, and from 0.15 gram at 125% rating to 0.7 gram per 100 cubic feet at 150% rating when burning a high-sulphur coal. The average values at boiler ratings of from 133 to 183% for the low-sulphur coal and from 125 to 192% for the high-sulphur coal were 0.8 and 0.5 gram per 100 cubic feet, respectively.

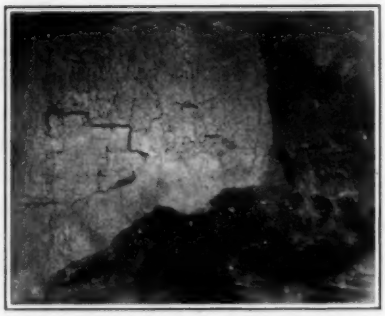

FIG. 11.—Interior of underfeed stoker-fired furnace after burning high sulphur Pittsburgh coal.

The values obtained in the powdered coal furnace burning Illinois coal at the zone of greatest erosion were from 19 to 22 grams at 190% rating and 34 to 63 grams per 100 cubic feet at 240% of boiler rating.

Arranged in the order of increasing severity of slag erosion the furnaces studied would be as follows: (1) underfeed stokers, (2) chain-

grate stokers, (3) powdered coal. Although other reasons for this varying severity of service have been pointed out it is interesting that the values for the quantities of slag carried in the gases fall in the same order. Of course the severity of service does not increase in the same proportion because only a certain amount of slag can attack the walls. Beyond the point where slag is deposited as fast as the molten combination runs away, further additions probably do not increase the action on refractories.

Conclusion

The significance of six service factors, namely, refractories temperatures, furnace gas temperatures, composition and velocities, and slag composition and quantities, which govern the slagging of boiler furnace refractories has been discussed and the range of their values under various conditions has been presented. Those who desire more complete data on these factors are referred to the progress reports on the investigation.[1]

Acknowledgments

This investigation is being carried on under the general direction of the Special Research Committee on Boiler Furnace Refractories of the A. S. M. E. of which C. F. Hirshfeld is chairman, and of P. Nicholls, fuel engineer, Bureau of Mines. Acknowledgment is made of the coöperation and helpful suggestions given by G. A. Bole, formerly superintendent of the Ceramic Experiment Station of the Bureau of Mines, and by S. J. McDowell, superintendent of the Columbus Branch of the Bureau of Standards. W. E. Rice and L. B. Berger of the Pittsburgh Experiment Station of the Bureau of Mines have been engaged on part of the field work. The analyses of coal ash and slag samples were made in the analytical laboratory of the Bureau of Mines under the direction of W. A. Selvig, and the softening temperatures of the coal ash under the direction of H. M. Cooper.

[1] R. A. Sherman and W. E. Rice, "Refractories Service Conditions in Furnaces Burning Pittsburgh Coal on Chain Grates," *Mech. Eng.*, **48,** 1115–22 (1926). R. A. Sherman, W. E. Rice, and L. B. Berger, "An Investigation of Boiler-Furnace Conditions as Related to Refractories Service," *Mech. Eng.*, **48,** 1389–96 (1926). R. A. Sherman, "Temperatures in Powdered Coal Furnaces Equipped with Extended Radiant-Heat Absorbing Surface," *Mech. Eng.*, **49,** 335–38 (1927).

THE EFFECT OF SIZE OF GRAIN UPON THE PROPERTIES OF SILICA CEMENT[1]

By Sandford S. Cole[2]

ABSTRACT

A thorough study has been made of the effect of size of grain upon the softening point and linear change of silica cements prepared in the laboratory. The ratio of grain sizes in a cement of constant chemical composition has a distinct effect upon the softening point. The linear change after heating to 110°C and 1300°C was not appreciably affected by variation in grain size.

From data obtained by testing a large number of commercial cements it is concluded that, owing to variations in clay content, screen analyses are not definitely related to rate of settle or to softening point. A method for determining "rate of settle" is described.

Introduction

The use of a high silica mortar as the bond material for brickwork in by-product coke ovens and acid open-hearth steel furnaces has been practiced ever since silica refractories have proved successful in such service. The mortar is more generally known as "silica cement." It consists of a mixture of finely ground ganister, bats, and fire clay so compounded that the cement contains approximately 90 to 93% silica. Previous writers have presented to the industry a rather thorough study of the necessary tests for such cements in order to determine whether they will prove satisfactory in service. Montgomery[3] studied the relation between the softening points and chemical composition of silica cements, and compared his results with the equilibrium diagram of the system silica-alumina. An outline of the necessary tests and a general discussion of the results were the main points taken into consideration. Montgomery recommended limits of composition and discussed the question of clay content and working properties. E. N. McGee,[4] in a more recent paper, studied the bonding properties, the refractoriness, and the screen analyses of silica cements.

The subject of the effect of grain size upon the properties of the cements has been mentioned by these investigators. The cements were considered merely in the light of the commercial product supplied by the manufacturer and not with respect to the properties produced by varied grain size.

Scope of Investigation

It is known that cements with screen analyses of quite varied ratios may have like properties. The present study was made in order to

[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., Feb., 1927. (Refractories Division.) Received January 10, 1927.

[2] The Koppers Company Laboratories, Mellon Institute, Pittsburgh, Pa.

[3] *Proc. Amer. Soc. for Testing Materials;* **18,** [II], 350–62 (1918).

[4] *Jour. Amer. Ceram. Soc.*, **6,** 896 (1923).

determine exactly the effect of the size of grain upon the properties of silica cements. In such cements the three variables causing a change in the properties are: (1) chemical composition which affects the softening point, (2) clay content which affects the rate of settle (or plasticity) and softening point and, (3) screen analysis which may affect the refractory properties and plasticity of the cement.

The present investigation can be divided into two sections, *i.e.*, (1) tests upon laboratory mixtures in which the percentage of clay was definitely controlled and the screen analysis varied, and (2) tests upon cements which were manufactured for use in coke ovens. The cements which were made with definitely controlled clay content were prepared in order to determine the effect of size of grain upon the softening point and linear change. Cements representative of the mortars being employed in plant construction were studied in order to establish, if possible, a relation between the screen analysis and the plasticity of the cement.

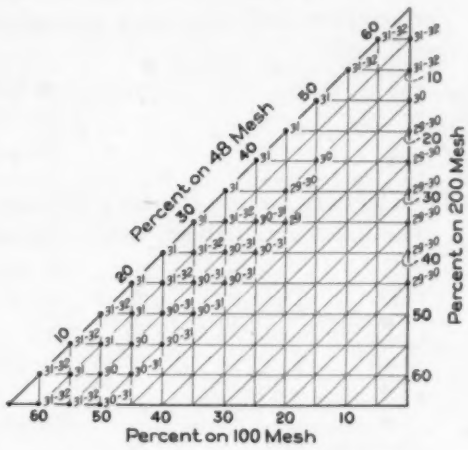

FIG. 1.—Softening point of mixes with 35% through 200-mesh.

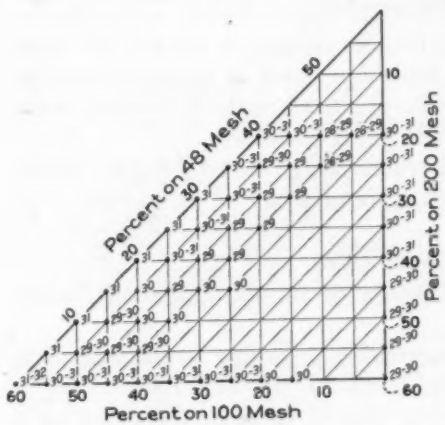

FIG. 2.—Softening point of mixes with 40% through 200-mesh.

It was thought that the plasticity and bonding properties of silica cements might be improved by using the correct proportions of certain grain sizes. Finely-ground cement has a high plasticity factor and good bonding properties, but the softening point is lowered due to the fineness of grain which aids the reaction between the alumina in the clay, and the silica in the ganister and bats. However, a cement which has a high softening point may not have sufficient bond between the grains to produce a strong cement.

Materials Employed

The cements were prepared in the laboratory from the same materials used in commercial cements, namely, ground ganister and bats obtained from the Mt. Union district, and a highly siliceous plastic clay. The ganister and bats were ground and screened into the following four sizes:[1]

Through 20- on 48-mesh
" 48- " 100-mesh
" 100- " 200-mesh
" 200- mesh

The clay was ground to pass a 200-mesh screen.

The following analyses were obtained for the materials used:

	Ganister	Bats	Clay
SiO_2	98.15	95.82	75.30
Al_2O_3	0.55	0.85	17.40
Fe_2O_3	0.47	0.53	0.26
CaO	0.10	2.05	0.40
MgO	0.10	0.10	0.10
Alk. comb.	n. det.	n. det.	n. det.
Ign. loss	—	—	5.50
Softening point	34	31–32	28

The cements employed in oven construction vary in composition, screen analyses, and softening point. It is not possible to obtain cements of constant analysis, since the materials which make up the cement usually have slight unavoidable variations in composition.

Tests Performed

As has been stated previously, this investigation covers the tests made on cements prepared in the laboratory and on cements received from the manufacturer. The cements prepared in the laboratory were tested for (1) softening point, and (2) linear shrinkage.

The cements from the manufacturer were tested for (1) screen analysis, (2) softening point, and (3) rate of settle or plasticity.

Description of Tests

The tests were made in accordance with standard methods, when such methods were available.

1. The softening points were determined according to the Standard A.S.T.M. Method (Standards 1924, C–24–20, pp. 745–47).

2. The samples were screened wet, that is they were washed on a 200-mesh screen until all the fine material had been removed from the cement. The sand remaining on the screen was then dried at 110°C and screened in a nest of 20-, 48-, 100-, and 200-mesh sieves.

[1] Tyler Standard Screens were used in all tests referred to in this paper.

3. The linear shrinkage was obtained on 1 by 1 by 6-inch bars molded from cement to which had been added 16% moisture. The shrinkage was obtained at 110°C and at 1300°C (2372°F). The firing of the cement was carried out in a gas-fired furnace with the bars protected from flame impingement.

4. The "rate of settle" method had to be developed in order to obtain a technically controlled test. Using a cement which was accredited by the bricklayers to be satisfactory, and another, which could not be used, due to settling out, a set of tests was made in conjunction with practical tests on the cement in the field. It was found that the test developed in the laboratory checked very closely with the experience of the bricklayer as to the settling out of cements. The test consisted in making a slip of the cement using 50% by weight of water and placing it in a stoppered graduated cylinder. The amount of water rising to the top of the mortar column was read directly from the graduations on the cylinder. The rate of settle in the first eight hours and at the end of twenty-four hours was obtained. Mortar as normally used in the field contains from 28 to 32% moisture, and this method gives an accelerated test which has proved quite satisfactory in predicting the nature of a cement when made into mortar.

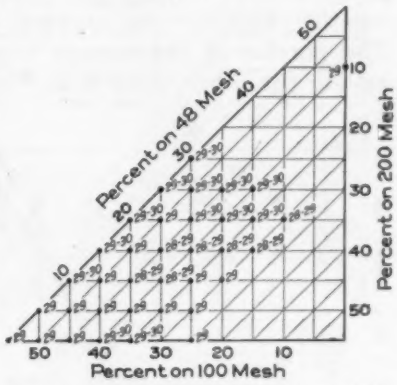

FIG. 3.—Softening point of mixes with 45% through 200-mesh.

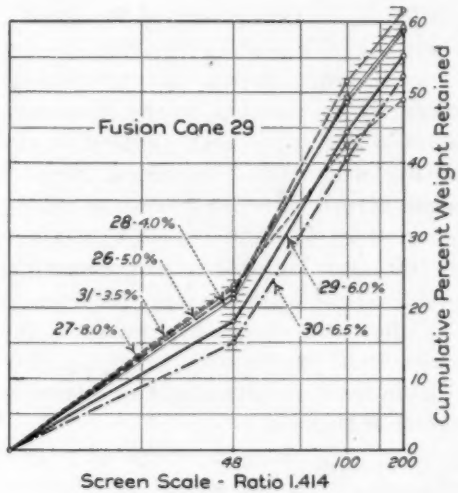

FIG. 4.

Limits of Investigation

The laboratory mixtures of cements were compounded from 25% clay, 50% bats, and 25% ganister, which represents the approximate composition of the commercial cements tested. Since commercial cements normally

contain 35% to 45% of material passing through a 200-mesh sieve, three series of laboratory mixtures were made which contained 35%, 40%, and 45% respectively, of material through 200-mesh. In each case the fines through 200-mesh consisted of all of the clay (25%) together with varying amounts of fines from the bats and ganister. The portion of the cement coarser than 200-mesh was distributed among the other three sizes, the amount of any given size varying from 0% to the possible maximum, 55 to 65%. Some of the combinations in grain size would not be encountered in practice, but were tested in order to determine the effect of each grain size upon the properties of the cement.

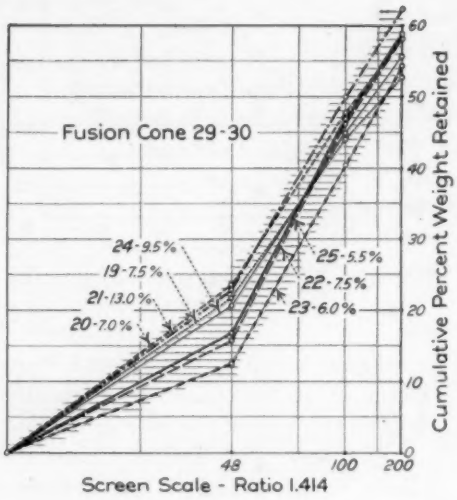

FIG. 5.

Outline of Results

Owing to the very large amount of data obtained in the various tests, it was deemed advisable to present these results in a set of curves (Figs. 1 to 7).

Discussion of Results

The screen analysis of each mix shown on the triaxial diagrams (Figs. 1 to 3) is indicated by its position on the diagrams. The sum of the three constituents which have been plotted is the percentage coarser than 200-mesh, to which must be added the percentage passing through a 200-mesh screen in order to obtain 100%. On these three diagrams the "per cent on 48-mesh" is read from the horizontal lines, the "per cent on 100-mesh" is read from the vertical lines, and the "per cent on 200-mesh" is read from the diagonal lines.

1. Figure 1 shows the effect of the ratio of grain sizes upon the softening point of cement when the total percentage through a 200-mesh screen is 35%. It is evident from these results that the softening point of a cement which has a screen analysis of

0–30 % on 48-mesh
20–65 % on 100- "
0–15 % on 200- "
35 % through 200-mesh

should not fall below cone 29. In the field which is most often encountered,

10–30 % on 48-mesh
20–40 % on 100- "
0–15 % on 200- "
35 % through 200-mesh

the softening point is 30–31 to 31–32 Orton cone for laboratory mixtures.

2. The series of tests in which 40% through 200-mesh was used is shown by Fig. 2. In this series the first strong evidence of the change in softening point by the variation in grain size is brought out. The field which is generally encountered is

10–30 % on 48-mesh
20–40 % on 100- "
5–15 % on 200- "
40 % through 200-mesh.

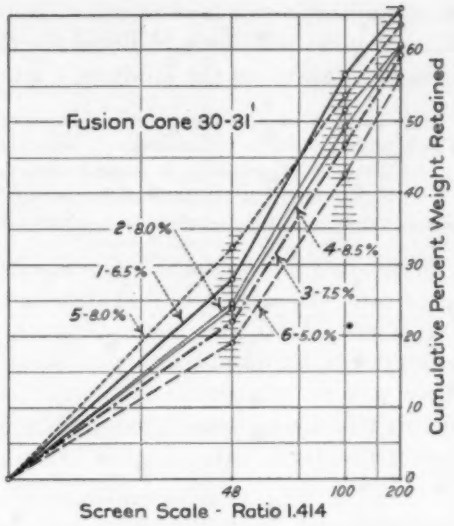

FIG. 6.

The softening point of laboratory mixtures in this field is from cones 29 to 30–31.

3. As the fineness of the mixes increased the softening point was lowered as may be seen by Fig. 3. In this series the percentage through 200-mesh was 45%. The effect of the size of grain on the softening point was quite evident in this set of mixes. The softening point was lower than in the other series being from cones 28–29 to 29–30. In the field generally encountered, *i.e.*,

10–30 % on 48-mesh
20–40 % on 100- "
5–15 % on 200- "
45 % through 200-mesh

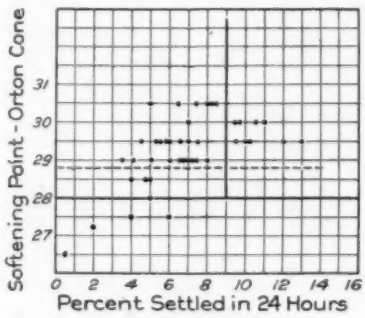

FIG. 7.—Rate of settle *vs.* softening point.

the softening point varies from cones 28–29 to cones 29–30 for the laboratory mixtures.

4. The effect of grain size upon linear shrinkage at 110°C and 1300°C has been studied for cements having 35%, 40%, and 45% of material through a 200-mesh sieve. Since the maximum variation was plus or minus 1%, the data are not presented in graphic form.

5. The relationships between screen analyses, softening points, and rate of settle for a few of the typical commercial cements which have

been studied in this investigation are presented in Figs. 4, 5, 6, and 7. These figures will serve to illustrate the following conclusions, which have been based on the study of a much larger number of cements.

(*a*) There is no apparent relationship between rate of settle and screen analyses. This is probably due to variations in clay content.

(*b*) Slow settling cements, in general, have a low softening point. See Fig. 7.

(*c*) Screen analyses are not satisfactory for predicting the softening point of commercial cements, since variations in clay content occur.

6. In the "rate of settle" test which has been described, commercial silica cements settled out at different definite rates during the first four hours. After four hours, the rate of settle rapidly decreased until seven hours, followed by very slow settling until 24 hours, after which there was no perceptible change. Cements which settle out rapidly in this test are not easily handled in practice, and it is recommended that a standard "rate of settle" test be adopted.

Acknowledgment The author wishes to acknowledge the assistance of J. A. Shaw in making the chemical analyses of materials used in this investigation.

Correction

R. F. Geller, "Bureau of Standards Investigation of Feldspar—Second Progress Report," *Jour. Amer. Ceram. Soc.*, **10**[6], 411 (1927). In this paper acknowledgment for samples of feldspar was made to R. V. Knowles. This name should have been R. V. Miller.

CERAMIC ABSTRACTS

Compiled by the

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Abrasives

A proposed method of testing the serviceability of loose grinding materials. W. MINDT. *Glasindustrie*, **34**, 321, 345, 370, 391, and 406(1926).—The efficiency of grinding materials depends primarily on the property of hardness. All known methods of testing hardness are "passive." A very full summary and complete bibliography on the subject of the testing of hardness are given. M. has developed an "active" method, in which the material to be tested is ground between 2 slabs of glass under standardized conditions in a machine resembling a lens-grinding machine. Experiments with different grades of emery prove that with continuous addition of grinding material at a constant rate, and with the addition of water at a rate sufficient to insure removal of glass splinters and grains of grinding material, the grinding velocity as measured by the rate of removal of material from the glass slabs is strictly proportional to time, and is independent of the grain size of the grinding material. This active method involved, n addition to the 5 factors which governed passive hardness tests, a further variable,

viz., the quantity of grinding material employed. The actual tests were carried out with a fixed amount of grinding material. Mathematical treatment of the results show that $a = G\sqrt{S(1-e^{-c.t})}$, where a is the "grinding service" (weight in grams of glass removed) in the time t, G is the "specific total serviceability" of a grinding material, S is the quantity in grams of grinding material, and c is a constant for any particular material. Curves calculated from this relation agree extremely well with those obtained experimentally. The final criteria of the serviceability of a grinding material are G and c. As G is a simple proportional factor, it can be used as a number alone, whereas c being an exponential factor, is less suitable. c, therefore, is used in the product cG, the "initial grinding velocity," which is independent of S, the quantity of material. The results are:

Material	$G \times 10^3$	$c \times 10^5$	$Gc \times 10^8$
Quartz sand	42	64	27
Corundum (German Norton Co.)	142	107	152
Corundum (Dynamidon)	113	139	157
Corundum (emery)	142	114	162
Tungsten-carbide (Lohmann)	163	106	168
Novo-diamantin (corundum)	163	106	168
Corubin	127	193	246
Corundum (Aloxite)	142	200	284
Volomit 21 (Lohmann)	234	138	310
Silicon carbide (Carborundum)	122	229	485
Diamond	∞	?	495
Volomit 13 (Lohmann)	296	194	575

Only in cases of coincidence, where the constants c are of the same value, can the results be directly compared with the hardnesses. The results are not absolute, since the factors, pressure, velocity, expansion of the total grinding surfaces, etc., although taken into account and controlled, are not determined numerically. Qualitative tests with differing loads show that with increase of pressure the grinding serviceability increases to a maximum (obviously where the grains are suddenly crushed) and then decreased rapidly. Tests with continuous supplying of emery at constant rates show that the grinding velocity increased to a maximum and then decreased. The maximum point was that at which the maximum number of grains lay between the 2 disks in a single layer. More than 3,000 experiments were made. (*Jour. Soc. Glass Tech.*)

PATENTS

Nonslip floor construction. FRANK J. TONE. U. S. 1,629,185, May 17, 1927. A nonslip floor surface including a supporting mass of cement having plane-faced fragments of a flat slab of abrasive material embedded in the upper surface thereof to a uniform depth and with the plane upper faces of the fragment substantially flush with the surface of the mass in which they are embedded and exposed to present a tread surface.

Waterproof abrasive fabric. FRANK JOSEPH CRUPI. U. S. 1,629,259, May 17, 1927. As a new article of manufacture a sandpaper product comprising a fabric base and abrasive material adhesively associated with the base by waterproof cellulosic coating material, the coating material containing a filler and also an emollient to maintain flexibility in the filler and the associated cellulosic material.

Bond for elastic grinding wheels and method of applying the same. EDWARD ANDERSON. U. S. 1,631,113, June 1, 1927. The method of coating grains of abrasive material, which comprises dissolving shellac in a volatile solvent, putting the required quantities of the solution and granulated abrasive material into a mixer and mixing thoroughly, adding a desired quantity of linseed oil and continuing the mixing constantly until the solvent has evaporated.

Art

A study of color and its application to ceramic art. THEODORE LENCHNER. *Jour. Amer. Ceram. Soc.*, **10** [7], 538–42 (1927).—Color is recognized as having 3 dimensions, (1) warmth or coolness, known as *hue*, (2) lightness or darkness, known as *value*, and (3) brightness or dullness, or strength or weakness, known as *intensity* and *chroma*. Two existing color theories, the Prang and Munsell system, are outlined. The proper application of colors is discussed.

Form and color in American Indian pottery north of Mexico. M. R. HARRINGTON. *Jour. Amer. Ceram. Soc.*, **10** [7], 543–49 (1927).—Common features in American Indian pottery are the facts that it was strictly hand made without use of any form of the potter's wheel and that it was never really glazed. Due to development of the art in different ways, it is possible to distinguish 7 different districts in America. A consideration of the pottery of each district is presented.

The Delaware River bridge between Philadelphia and Camden. HAROLD D. EBERLEIN. *Arch. Rec.*, **61** [1], 12 (1927).—A noteworthy feature of this bridge is the use of 4 sets of 9 each polychrome tile medallions using motifs representing transportation by land, water, and air from the early stage coach to the dirigible, placed in the walls of the lift lobbies in the anchorage towers. The design is well adapted to the vigorous treatment in the medium. (Illustrated.) E.B.H.

North Italian brickwork. M. B. SMITH. *Arch. Rec.*, **61** [1], 65–74 (1927).—A series of articles to present an intimate study of brick and brick detail used in the Lombard plain of Italy from the Middle Ages through the Early Renaissance, this being the period of finest expression in brick design. Many inspirational illustrations show: (1) an informal effect with bricks laid in a mortar bed with small cobble stones and irregular stone work alternating, the mortar contains coarse sand and small pebbles and is probably unscreened material from river sand beds; (2) alternate courses of large brick with small ones, producing a superior color effect, the large brick are light salmon, sun-dried, the small vitreous ones a deep reddish brown, Verona also alternates brick with stone; (3) herring bone work with odd dimensional stretchers and headers laid in wide joints and uneven courses; (4) varied features unique chiefly for the crinkled surface of its hand made brick, made without a mold; (9) the scratched surface, the means of keying gesso to brick; (14) a suggestion,—just enough mortar was spread, then the brick tapped into place squeezing out a bead which gives an irregular shadow; (16) vertical joints smoothed, producing a stratified effect; (18) alternate courses projecting which may interest some designer. Each brick in a Lombardy wall has its own color, size, and shape, yet keeps its place as part of the whole, no doubt due to irregular bonding. Plates of measured drawings and photographs are included throughout the entire series. *Ibid.*, **61** [2], 161–71 (1927).—A vigorous and brutal cornice of darkly fired brick with gesso in the recessed panels is shown having but a 20-inch projection for its 5-foot height. The average size of Italian brick is 3 by 5 by 11 inches. Figure 9 shows brick work carved after building into place, the tool marks visible. A combination of brick, marble, and terra cotta in perfect harmony of function and decoration is illustrated. *Ibid.*, **61** [3], 257–68 (1927).—The brick enthusiast must speculate on the cohesive virtures of the mortar that has held leaning towers from falling for 800 years. Santo Stefano, the first and loveliest of brick buildings is the shrine of sainted brickwork. The mosaics of the walls range in color from yellow through orange to deep red and reddish brown. The brick has a variety of surface textures, sand and water struck, smooth and pitted. It is combined in patterns with creamy white marble, sand stone, and dark green porphyry. Plate II illustrates the rosettes occurring in the spandrels of the Atrio di Pilato. The centers are saucer-shaped majolica inserts highly glazed and decorated to harmonize with the brick and marble pattern. In the modern church of

the Sacred Heart the lack of color variation in the bricks inclines the effect toward the metallic. *Ibid.*, **61** [4], 360–71(1927).—In the Lombard Gothic period terra cotta came into general use permitting fine scale ornament to be repeated indefinitely. Carved brick continued popular. Another typically Gothic motif is the cone-shaped termination of the tower always executed in hard fired bricks with semicircular molded ends to the weather. Plate II shows free use of flat tile and brick employed extraordinarily in chimney tops, the ingenuity of which passes belief. *Ibid.*, **61** [6], 521–32(1927).—Small diamond billets were molded on the brick. Archivolt bricks were rubbed to fit. Excellent illustration of use of pattern brick is shown, the bricks probably cut after laying. E.B.H.

Polychrome figures. ANON. *Arch. Rec.*, **61** [3], 193(1927).—Colored illustrations of 2 figures in polychrome forming part of the pediment designed by Paul Jenniwein for the Philadelphia Museum of Art, Fairmount Park, Philadelphia. E.B.H.

Decorative painting on concrete. S. F. ROSS AND N. C. JOHNSON. *Arch. Rec.*, **61** [4], 289–300(1927).—The trend toward economy and frankness in construction and expression has encouraged a wider resort to color in architecture and the use of concrete as a base for applied decoration. The Temple House for the Union Temple of Brooklyn is an example of this painting on the exposed concrete surface. In the ceiling the structural members were placed to conform to the given design and false beams added as required. The chemistry of the concrete presents several problems. (1) It is subject to a constant change. Only a small percentage of the cement used is taken up on the initial set and more and more of this unused cement becomes active as time goes on. (2) The bottom of the form is covered with a rich skin cement coating which dries faster than the mass causing fractures throughout the undersurface. Therefore the base coating must have considerable penetration and be of a substance not affected by dampness or the chemical reactions in the concrete causing deterioration and disfiguration or permitting efflorescence and saponification. The surface must also be capable of receiving and retaining oil paints and pigments without destroying their permanency. The formula devised contains a cellulose base plus enough color to permit visual inspection, insuring a thorough coating. The penetration attained was $\frac{3}{8}$ to $\frac{1}{2}$ inch. Two coats of the base were applied leaving a remarkably good texture on which an especially prepared lead and oil paint with various pigments was used. In figure decoration the outlines were for the most part pounced on or drawn direct and filled in by hand, while stencils were used for the smaller beam decorations. The coloring being extremely brilliant the entire ceiling was glazed down to the required tone after completion. The effect is not garish. Cinder concrete often used as a matter of economy is not dependable on account of the possible poor quality of present day cinders and the chemical reaction of the sulphur content on the base coat of paint. E.B.H.

Water essential to certain types of gardens. HELEN BISHOP. *Arts and Dec.*, **27** [2], 40–43(1927).—Illustrates (1) a wall fountain showing bronze peacocks against a background of intense blue tile and (2) a fountain pool enclosed within tiled walls. E.B.H.

Cradles of the past. DOROTHY BENT. *Arts and Dec.*, **27** [2], 58, 59, 86(1927).—Illustration of cradle whose sides have a border of decorated tiles. E.B.H.

The stained glass of Hans Holbein, the elder, in the cathedrals at Eichstatt in Franconia. ANON. *Diamant*, **48** [16], 306–307(1926).—The stained glass windows created by the elder Hans Holbein in cathedrals at Eichstatt are described. E.J.V.

Glass and mosaic works of art in the Gallery for Christian Art in Munich. K. *Diamant*, **48** [18], 349–50(1926).—A discussion of the artistic glass and mosaic works of Wilhelm Pütz to be found in Munich's "Gallery for Christian Art." E.J.V.

Of the origin of the colored glasses used in stained glass windows of the Middle Ages. JOHN A. KNOWLES. *Diamant*, **48** [18], 347–49; [19], 370–71; [20], 387–89; [22], 426–29; [23], 449–51; [24], 468–70(1926).—A historical discussion of the places of origin and discoverers of the various colored glasses used in the stained glass windows produced in the Middle Ages. The literature covered is referred to. E.J.V.

Glass gilding. W. H. *Diamant*, **48** [24], 464–66(1926).—For glass gilding 3 solutions are necessary: gold chloride solution, soda lye solution with a specific gravity of 1.06, and a reducing solution made up of acetaldehyde, acetic and formic esters, alcohol, inverted cane sugar, and water. The preparation of the mirror is done by mixing 1 part of the soda lye with 4 volumes of the gold solution and adding 3% of the total volume of the reducing solution and then bringing the surface to be gilded into contact with this solution. The gold is deposited slowly on the glass, taking about 3 hours at 15°C. The speed of deposition is increased by raising the temperature up to 60°C. Other methods are also discussed. E.J.V.

The Augsburg stained glass worker Jörg Prew, the elder. ANON. *Diamant*, **48** [25], 484–86(1926).—A biographical sketch of Jörg Prew and his works. E.J.V.

New motives in stained glass. Z. *Diamant*, **48** [26], 506–508(1926).—A discussion of the trend of motives in modern stained glass productions. E.J.V.

On the production of magnificently colored glass Christmas tree ornaments. OTTO W. PARKERT. *Diamant*, **48** [26], 509–10(1926).—Materials and methods used to produce colored glass ornaments for Christmas trees are discussed. E.J.V.

Of the Cologne cathedral windows. Z. *Diamant*, **48** [28], 542–43(1926).—A note on the stained glass windows of the middle ages found in the cathedrals in Cologne. E.J.V.

Matt etching and decoration of glass. W. H. *Diamant*, **48** [29], 567–68(1926).—Matt etching of designs may be done by tracing them with an intimate mixture of 2 parts cryolite, 1 part borax, and $\frac{1}{2}$ part pure red lead, and then heating the glass in a decorating muffle kiln. Electrolytic etching of glass by use of a concentrated solution of potassium nitrate for a conducting medium over the glass surface and tracing the design with an insulated stylus which is one pole of the circuit while the solution is the other is described. Semitransparent or crystalline decorations are produced by use of alkali hydrate, such as soda, as a drawing medium and then heating the glass to a dull red heat. Glass decoration by heat treatment is covered by altogether too many methods, some of which are enumerated. Designs on dark glasses are made by use of stencils and an enamel consisting of 2 parts tin oxide, 1 part lead oxide, 6 parts of a flux consisting of 100 parts quartz, 300 parts potash, 400 parts borax, and 150 parts arsenic. The production of silver or aluminium characters, and frostwork or damask decoration on glass are described. E.J.V.

Contribution to the technic of ceramic decoration. KARL JACOB. *Tonind. Ztg.*, **50** [50th Anniv. No.], 41–43(1926).—A description of the different types of decoration and the metallic oxides used to obtain the different colors. F.P.H.

Concerning cobalt underglaze decorations. WOLFGANG HENZE. *Keramos*, **6** [2], 55–57(1927).—A description of the cobalt compounds used in glazes. Several batch formulas are given which yield various shades of blue. F.P.H.

The Royal Ontario Museum of Archaeology. C. T. CURRELLY. *Univ. of Toronto Monthly*, **27**, 347–50(1927).—In the collection of Chinese pottery, the museum at Toronto now leads the world. This is due largely to the knowledge and energy of George Crofts of Tientsin, China, who died 2 years ago. Lawrence Binyon of the British Museum, London, after seeing the Crofts collection, wrote that everyone would come to this museum to study. H.H.S.

Investigation of porcelain colors: phosphate and titanate colors. W. MUTHMANN AND H. HERAMHOF. *Ann. Chem.*, **355**, 144 (1907).—Experimental work on porcelain colors prepared from the phosphates and titanates of the rare earths neodymium, praseodymium, and cerium, and of iron, cobalt, nickel, manganese, and chromium is reported. Trials were fired in an electric laboratory furnace up to 1450°. The colors are indicated by reference to Radde's international color scale. (1) Neodymium phosphate may be fired either in an oxidizing or reducing atmosphere up to 1450° without risk. It gives a translucent pink, closely resembling flesh color. (2) Praseodymium phosphate is also very refractory, and gives, in a thick layer, a beautiful leek-green. (3) Ferric phosphate, prepared by hot precipitation from a dilute solution of ferric chloride with sodium phosphate and ammonia, must be thoroughly calcined in an oxidizing atmosphere and well ground, otherwise a brown color instead of a pale yellow is produced. (4) Manganous phosphate, prepared by precipitation from a boiling neutral solution of manganous chloride with neutral ammonium phosphate, decomposes at the temperature of the porcelain oven and produces a dirty yellowish-brown color. (5) Cobalt phosphate was precipitated with neutral ammonium phosphate from a cobalt nitrate solution. The precipitate must be well washed, calcined, ground, and sifted through a fine cloth. On porcelain it gives a deeper blue than the oxide and silicate; it is also more refractory and unites strongly with the body and glaze. (6) Chromic phosphate, prepared (*a*) by hot precipitation with ammonium phosphate from chromic nitrate, gives a light grass-green color, like the oxide, (*b*) by evaporating to dryness freshly precipitated chromium hydroxide and concentrated phosphoric acid, and calcining, it gives a somewhat darker green. By adding sufficient phosphoric acid to correspond with an acid phosphate a remarkably fast color, slightly lighter than the other is produced. All the chromium pigments were exceptionally refractory; they showed no signs of "running" at 1450°. (7) Copper and nickel phosphates were found unsuitable for porcelain. The reaction between silica and cobalt phosphate at high temperatures was studied. No reaction took place between 500 and 900°. Cobalt-silico-phosphate began to form at about 1000°. (8) Iron titanate was prepared by fusing a mixture of precipitated iron oxide and pure titanic acid, or by dissolving these two substances in concentrated sulphuric acid and precipitating with ammonia. Orange-red color was obtained by carefully avoiding reducing conditions. (9) Ceric titanate produced a "fast," bright yellow on firing to 1400°. The titanate was prepared by precipitating with ammonia from a mixture of 1 part cerium-ammonium nitrate and 3.1 parts of titanic acid. (10) Manganese titanate a mixture of 1 part of mangano-manganic oxide, 4 parts of titanic acid, 1 part of zinc oxide, and 1 part of cadmium oxide, when fired on porcelain, produced a strong reddish-yellow, which showed no signs of "flowing" at the highest temperatures. By varying the proportions of the ingredients in a mixture of mangano-manganic oxide, titanic acid, and cerium-ammonium nitrate, colors varying from pure yellow to orange are possible. (*Trans. Ceram. Soc.* [Eng.])

Production of pressed glass cameos, buttons, etc. ANON. *Die Perle*, **3**, 79 (1926).—In pressing small articles having a flange and reëntrant sides in one-piece molds, an inlay made of metal easily soluble in acid but resistant to white-hot glass (*e.g.*, brass) is put in the mold to form the reëntrant angle. After the articles have been pressed and cooled, the metal inlay collar is dissolved off by immersion in a suitable acid-bath. For articles with no flange a metal collar which incorporated a fastening is used. After pressing, the collar is easily removed after undoing the fastening. Conical depressions in glass objects are made by pressing in metal cones, and after cooling, dissolving out the cones by the aid of a suitable acid. (*Jour. Soc. Glass Tech.*)

The development of glass decoration. B. MAUDER. *Keram. Rund.*, **34**, 536 (1926).—The connection between the types of glass decoration used and the contemporary

kind of metal and technique available was traced for the different periods and localities of glass production. Imitations of ancient and medieval forms of decorative ware, made by using modern materials and technique, were condemned. (*Jour. Soc. Glass Tech.*)

Preparation of white glazes and enamels without tin oxide. W. HENZE. *Keram. Rund.*, **34**, 193 (1926).—A number of opacifying media in various mixtures were tested. Boric acid and borax favored opacity most. A few mixtures with antimoniates gave good white glazes; zinc oxide gave less satisfactory results. Zirconium oxide is the best substitute for tin oxide. Recipes and results with other opacifiers are communicated. (*Trans. Ceram. Soc.* [Eng.])

Cologne brown stoneware. C. STÜRMER. *Keram. Rund.*, **34**, 139 (1926).—The preparation and firing of old Cologne brown stoneware are described. Methods of reproducing this ware are considered, a number of suitable body mixtures being given. (*Trans. Ceram. Soc.* [Eng.])

BOOKS

Catalog of the George Eumorfopoulos Collection of Chinese, Corean, and Persian Pottery and Porcelain. Vol. IV: The Ming Dynasty. R. L. HOBSON. London: Ernest Benn, Ltd., 1927. Price 12 guineas. The edition, number of copies, etc. are the same as that of Vol. III (see *Ceram. Abs.*, **6** [1], 4 (1927). H.H.S.

Catalog of the George Eumorfopoulos Collection of Chinese Frescoes. LAURENCE BINYON. London: Ernest Benn, Ltd., 1927. Price 12 guineas. 560 numbered copies, of which 495 are for sale, and in the *edition de luxe* 25 copies, 20 for sale. There are 50 full page plates, all in color. H.H.S.

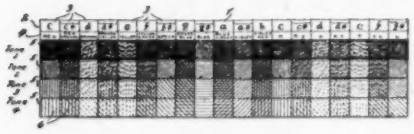
Spanish Art. Edited by R. R. TATLOCK. London: Batsford, 1927. Price 2 guineas. An introductory review of architecture, ceramics, sculpture, painting, etc., with over 120 plates, 9 in color. The book is one of the special monographs of the *Burlington Magazine*. H.H.S.

The Book of Porcelain. A. ZOELLNER. Translation by M. M. Morrow. London: Methuen & Co., 1927. Price 6 *s*. The above 4 books are reviewed in the *Illustrated London News*, May 21, 1927. H.H.S.

PATENTS

Method of and composition for transferring designs, pictures, and the like. HELEN JOHNSTON HURT. U. S. 1,629,165, May 17, 1927. A transfer solution comprising a vegetable oil, an alkali in chemical union and diluted to a syrupy consistency.

Means for determining color combinations. HAZEL H. ADLER. U. S. 1,630,247, May 31, 1927. A device of the character described comprising a plurality of rows of color indicating areas corresponding to the color sequence of a spectrum, each row including one entire range of the spectrum colors followed by a considerable part of a second identical range in the same order; the colors in each row being arranged in sequence according to the notes of a musical scale and the color area for each color in each row differing in tone or pitch from the corresponding color area in the other rows, the rows being so arranged that the different pitches or tones for each color are disposed in alinement in graduated relation, and means settable at any selected color in any row for thereby selecting from any of the rows three-color harmonious color combinations of which the selected color forms an element corresponding to harmonious musical combinations.



Cement, Lime, and Plaster

Gypsum, its preparation and uses. P. MARTELL. *Keramos*, **6** [3], 98–100 (1927). F.P.H.

Concerning faulty and old plaster molds. WOLFGANG HENZE. *Keramos*, **6** [3], 100–102 (1927).—A discussion of the cause of the deterioration of plaster molds. F.P.H.

Magnesium oxide cements. ANON. *Helv. Chim. Acta*, **10**, 140–67 (1927); *Rock Prod.*, **30** [11], 90 (1927).—The desiccation curves of the solid masses obtained by mixing magnesium chloride solutions with magnesium oxide have a point of inflexion corresponding with the presence in the partially dried mass of 6 mols. of water per mol. of magnesium chloride in addition to the water required to convert the oxide into hydroxide. For the crystallized oxychlorides the corresponding figure was 4.4 to 6.7. On rehydration, those specimens take up most water which contained most originally. If the solid cement is immersed in a 5N- or 8N-magnesium chloride solution, magnesium chloride is taken up relatively rapidly at first, then more slowly, the rate of absorption in this latter stage being the more rapid the less the amount of chloride originally present in the cement. After some time fine crystals appear near the cement, indicating that the chloride-oxide mixture contains even after setting unchanged oxide, which first dissolves in the concentrated chloride solution and then separates out as oxychloride. The smaller the amount of water used to mix the cement, the greater is its hardness when set as measured by the load necessary to break a cylinder of it supported horizontally at its 2 ends. The concentration of the magnesium chloride used to mix the cement must exceed a certain minimum value, which depends on the physical state of the oxide used, for setting to occur at all. With increase in the concentration beyond this value, the hardness of the cement increases at first rapidly and subsequently more slowly. For a given composition of the initial mixture, the hardness of the cement varies considerably with the fineness and mode of preparation of the oxide; in general the fine-grained oxide prepared from the oxalate yields the hardest masses. With increasing temperature, the minimum chloride concentration which will produce hardening increases. The hardening powers of the magnesium salts decrease in the order: chloride, bromide, sulphate, nitrate. On desiccation at the ordinary temperature the hardness increases slowly at first, then, when most of the water has been lost, much more rapidly. Rehydration causes the hardness to fall below its initial value. On dehydration at higher temperatures, the hardness commences to decrease again after a certain point, which, however, corresponds with no particular stoichiometric mass composition. The microscopical examination indicates that setting is not due to the formation of crystalline oxychlorides, but to the chloride solution causing the grains of oxide to swell owing to some chemical change in their interior, until they come into such close contact that they cohere. The effect of various salt solutions on the hardened cement has been examined. Ferric, aluminum, stannic, and cupric chlorides dissolve it to form colloidal solutions. Zinc and nickel chlorides harden it, whereas calcium and barium chlorides soften it. F.P.H.

Rotary kilns vs. shaft kilns for lime-burning. RICHARD K. MEADE. *Rock Prod.*, **30** [10], 56–59 (1927).—A comparison of installation and operating costs of both types of lime-burning plants. F.P.H.

Development of the German cement industry. C. R. PLATZMAN. *Rock Prod.*, **30** [11], 39–41 (1927).—The following subjects are discussed: (1) history of industry, (2) progress in kiln design, (3) special Portland cement, (4) cement from gypsum, (5) advance in standards. F.P.H.

Adhesion of mortar to sand-lime brick. ANON. *Rock Prod.*, **30** [11], 55 (1927).—A description of a number of tests made at the Bureau of Standards on the adhesion of mortar to sand-lime brick. F.P.H.

Benefits of standardization to cement industry outlined by Dr. Burgess. ANON. *Rock Prod.*, **30** [11] 59–60 (1927). F.P.H.

National Lime Association to reorganize as a federation of group organizations. ANON. *Rock Prod.*, **30** [11], 75–82(1927).—A report of the annual convention of the National Lime Association, May, 1927. F.P.H.

Quantitative determination of silica in cements by means of a membrane filter. HEINRICH HART. *Rock Prod.*, **30** [11], 90(1927).—H. describes a method developed at the Zementechemischen Institut der Technischen Hochschule zu Berlin in which the usual difficulties encountered in quantitative determination of silica are largely eliminated. The ordinary analytical methods yield the silica in a colloidal form, a state which makes necessary special apparatus and reagents, to get correct results. The method as developed is described below: A 1-gram sample of cement is mixed with 1 cc H_2O in a 150-cc beaker; it is then decomposed with 3 to 5 cc concentrated HCl (sp. gr. 1.19) being stirred to insure a complete reaction. The gel thus formed is placed in a warm sand bath or over the flame of a Bunsen burner, the heating being effective in transforming the last traces of the silica sol into gel. It has been found advisable to let the mass cool. It is then diluted with cold water up to about 100 cc, stirred vigorously to break up all gel lumps, filtered and washed well with hot diluted hydrochloric acid and with boiling water. The apparatus, consisting of a flat perforated porcelain disk, funnel, ring, stand, rubber stoppers and suction flask and pump, is cleaned. One or two filter papers are placed on the perforated disk and form the base for the membrane filter. The filtration process is thus distributed over the entire area of the membrane filter. The rate of suction is regulated by passing a little water through the apparatus. Washing is done with hot diluted hydrochloric acid and 8 to 10 times with boiling water. The apparatus is taken apart after the filtration is completed and the silica removed to a platinum crucible, previously weighed. As the latter step requires some skill, the difficulty is obviated by placing an extra dampened filter paper, 9 cm in diameter, upon the membrane filter. The silica is largely retained on the filter paper and can be easily lifted out and placed in the crucible. The quantity still remaining on the membrane filter can be scraped with a little piece of filter paper and also placed in the crucible. The crucible and contents are then dried to constant weight at 110°C. The increase in weight after allowing for the filter papers and membrane is calculated as SiO_2. A large number of cements and other silicates were tested in this manner. The results showed that the accuracy of the silica determination was independent of the kind of membrane filter used; the selection of the filtering medium thus is controlled mainly by considerations of time, as rapid filtering may sometimes be desirable. The reliability of this method of determination is evident not only from the accuracy of the value of silica content, but also from the fact that the values of sesquioxide content are no longer obscured by small quantities of silica. This was demonstrated successfully on a high strength special cement with very high content of sesquioxides. Additional tests were made of sodium-hydrosilicates to extend the procedure beyond the scope of cements. A perfect agreement was obtained with values given by the Association of German Portland Cement Manufacturers, operating in accordance with their methods.

F.P.H.

Effects of admixtures of $CaCl_2$ on properties of cements. KILLIG. *Zement*, No. 12, 224–26(1927); *Rock Prod.*, **30** [10], 92(1927).—K. shows that $CaCl_2$ may be easily added to the cement in the manner described without rendering difficult the grinding of the selected raw materials, provided these are previously dried at 180 to 200°C. Even very small admixtures of $CaCl_2$ have a beneficial effect on the strength of slag cement, which is probably due to the formation of basic calcium chloride possessing greater activity. Calcium chloride also has a beneficial effect on the soundness of slag cement. Cements manufactured with such admixtures show no undesirable changes, when cured properly. F.P.H.

Fifty years of the cement industry. H. MÜLLER. *Tonind. Ztg.*, **50** [50th Anniv. No.], 46–47 (1926).—A description of the principal improvements that have taken place during the last 50 years in the manufacture of cement. The improvements in the kilns are described. F.P.H.

Five decades of research on cements. HANS KÜHL. *Tonind. Ztg.*, **50** [50th Anniv. No.], 47–50 (1926).—A review of the principal contributions to the knowledge of the constitution of Portland cement. F.P.H.

Standards for Portland cement. HAEGERMANN. *Tonind. Ztg.*, **50** [50th Anniv. No.], 50–53 (1926).—The changes that have taken place in the standard methods of testing Portland cement during the last 50 years are traced. F.P.H.

Early high-strength cements. SPINDEL. *Tonind. Ztg.*, **50** [50th Anniv. No.], 53–54 (1926).—A description of the early high test cements. A method of representing a 4-component system on a parallelogram is described. F.P.H.

Grinding in the cement industry. TH. KLEHE. *Tonind. Ztg.*, **50** [50th Anniv. No.], 55–57 (1926).—A description of mills for the fine grinding of cement. F.P.H.

The development of lime kilns. E. SCHNEIDER. *Tonind. Ztg.*, **50** [50th Anniv. No.], 61–62 (1926).—A history of the development of the lime kiln. F.P.H.

Modern lime kilns. HORST LAEGER. *Tonind. Ztg.*, **50** [50th Anniv. No.], 62–63 (1926). F.P.H.

The development of sand-lime brick. B. KRIEGER. *Tonind. Ztg.*, **50** [50th Anniv. No.], 63–64 (1926).—A history of the development of the sand-lime brick. F.P.H.

Demands of the trass industry. E. GEBAUER. *Tonind. Ztg.*, **50** [50th Anniv. No.], 65–66 (1926). F.P.H.

Rate of carbonation of lime plaster. ANON. Bur. Stand., *Tech. News Bull.*, No. 121, pp. 9–10 (1927).—One of the first facts to be recognized concerning the properties of lime is that its combination with carbon dioxide of the air is the main reaction which leads to the formation of the bonding material of lime mortar and plaster. An investigation concerning the gathering of definite facts relating to the recarbonation process has been undertaken by the Bureau. Three different variables have been given consideration, (1) type of mortar, (2) richness of mortar, (3) the different surface coatings of the mortar. A description of methods used for testing and some results are given. It is concluded that since it is possible to produce a fairly impervious film of paint on a smooth surface, such as a 1 : 1 mortar, the advisability of applying an oil paint to the white coat of lime plaster before the underlying coats have completely carbonated is indeed questionable. R.A.H.

Portland cement in Canada. W. A. TOOHEY. *Can. Min. and Met. Bull.*, No. 181, 561–93 (1927).—A preprint of a paper to be presented at the Empire Congress at Montreal in August. Ruggles Wright made the first Canadian hydraulic cement at Hull (Quebec) in 1830. An amalgamation of cement firms took place in 1909. The production in 1926 was 8,351,644 barrels, not so high as the prewar record of 8,913,014 barrels in 1913. Numerous photographs are given of concrete buildings, canal-locks, aqueducts, dams, stacks, bridges, and highways in Canada. The competition of alumina cement is met by the following devices, (1) decreasing amount of mixing water, (2) increasing mixing time, (3) increasing amount of cement, (4) placing concrete at temperature at least 70°F, (5) keeping the concrete at 70°F for one day, (6) keeping the concrete damp, (7) using 2% CaCl in mixing water. By these means a compressive strength of 2429 lbs. per sq. in. was obtained in one day, 4655 lbs. in 7 days, and 5232 lbs. in 28 days. H.H.S.

Notes on silica material. BACH. *Tonind. Ztg.*, **50**, 253 (1926).—A waste product of the chemical industry, *viz.*, silica material in powder form, is suggested as an addition to Portland cement to prevent or retard the separation of free lime. This material was found to vary considerably in composition. The soluble silica content, which would

react with the lime, was not as high as expected. The tensile strengths of Portland cement-silica mortars are tabulated. The amount of water of hydration, *i.e.*, the structure of the material, has an important bearing on the strength.

(*Trans. Ceram. Soc.* [Eng.])

PATENTS

Cement, SO_2, and lime silicate from calcium sulphate. Brit. 244,078; *Rock Prod.*, **30** [10], 92 (1927).—Calcium sulphate is heated with silica or siliceous materials such as shale in the presence of steam and under an oxidizing condition to a temperature of about 1100° to produce SO_2 gas, lime silicate, or cement. Steam can be omitted if heating is carried on by fuels containing a large proportion of hydrogen; for example, oil, producer gas, from lignite, etc. F.P.H.

Process of heating lime to make lime blocks, stucco, etc. N. V. S. Knibbs. Brit. 245,935; *Rock Prod.*, **30** [10], 92 (1927).—Ordinary burnt lump lime is reduced to a granular condition, for instance, so as to pass a 30-mesh sieve, and is fed into an inclined rotary kiln similar to that used in burning Portland cement. At the lower end of the kiln, gas containing carbon dioxide and at a temperature of 700–800°C is introduced, the gas and lime passing in counter-current through the kiln. For the purpose in question the exhaust gases or combustion gases from a lime kiln or a furnace or from a gas producer or burner supplied with producer gas may be used. The rate at which the lime is fed through the kiln and the rate of withdrawal are controlled so as to secure sufficiently prolonged contact between the lime and the gases in order to attain the desired result; for instance, the time of transfer of the lime through the kiln may be 2 hours. When water vapor is used a rotary cylinder externally heated may be used and steam or water introduced into the end of the cylinder remote from that into which the lime is fed. The product obtained by treating lime in the manner described above is then ground, when it will be found that the product sets in the manner comparable with plaster of Paris. It may be mixed with ordinary hydrated or slaked lime to produce mixtures that will also set. The invention is particularly adapted for forming blocks or slabs of the character of gypsum block, the usual aggregate, water, etc., being added and the product molded. F.P.H.

Aluminous cements. Brit. 250,246; *Rock Prod.*, **30** [11], 91 (1927).—Raw cement materials are ground fine and heated to temperatures below clinkering point (about 1000 to 1100°C). The raw materials comprise limestones, clay, iron ore, and siliceous rocks. F.P.H.

Quick hardening cements with high lime contents. Brit. 264,711; *Rock Prod.*, **30** [10], 92 (1927).—Natural substances with high lime sulphate contents such as gypsum and anhydrite are previously and separately freed from all free moisture, finely pulverized and then cooled off. Slags and cement clinker are also separately dried to remove free and hydration water, finely pulverized, and cooled off. The anhydrite and cement clinker is ground finer than the slags. The 3 constituents are then intimately mixed under normal temperature in proportions varying according to the chemical compositions of the individual materials. The following proportions are given as preferable: slags, 80%, clinker, 5%, and anhydrite, 15%. The slags may be replaced if desired by natural cements and the anhydrite by gypsum whose water content has been reduced to 5% or less. The cement so made is said to be quick-hardening with an early high-strength. F.P.H.

Fused cement. G. Polysius. Brit. 434,187; *Rock Prod.*, **30** [10], 92 (1927).—The fused materials are run from the rotary kiln to a chamber where intimate mixing is given, flux being added if necessary, and the molten mass being then subjected to a reducing process. A nozzle, carrying the heating medium, is so arranged that the hottest part of the flame reaches the kiln outlet. The procedure can be developed on the counter-current principle. F.P.H.

Aluminous cement. Can. 265,818; *Rock Prod.*, **30** [10], 92 (1927).—A small amount of calcium chloride, fluoride, or cryolite, singly or together, is incorporated in the aluminous cement mixture before burning. F.P.H.

Making cement from refuse. G. E. HEYL. Brit. 259,503, May 31, 1926. Town refuse is calcined in a rotary furnace at a temperature not exceeding the melting point of the resulting ash. The ash is mixed with the necessary cement-forming ingredients (lime, etc.) and again calcined in a rotary kiln. (*Trans. Ceram. Soc.* [Eng.])

Enamels

The effect of mill practice on the working properties and finish of vitreous enamels. J. E. HANSEN. *Jour. Amer. Ceram. Soc.*, **10** [7], 517–23 (1927).—Variations in mill or grinding practice are shown to affect the working properties and finish of vitreous enamels. Uniform mill practice from day to day is necessary for exact color matches from day to day in some shades of enamels. Too small a mill charge contaminates the enamel with abraded pebble and mill lining material, and may therefore decrease the gloss and alter the color. Attention is called to the possibility of obtaining too much "set-up" in an enamel charge ground in a new or newly relined pebble mill. The particle fineness of the enamel may be tested by the usual screen test, or in a cone screen, which is described.

Good mixing reduces smelting cost. ANON. *Ceram. Ind.*, **8** [6], 664 (1927).—A description of a few features found at the plant of the Superior Enamel Products Co. A mixer which was found to give much better distribution of cobalt in the ground, cut down smelting time 25%, and give a better enamel is described. F.P.H.

Special oxide for acid-resisting enamel. WALTER KERSTAN. *Ceram. Ind.*, **8** [6], 665 (1927).—A formula of an acid-proof enamel used for cast iron sanitary enameled ware is given. The formula contains "Meltoxyn" which is said to increase the acid resistance of the enamel and act as an opacificer which is equal to that of tin oxide. The composition of "Meltoxyn" is not given. F.P.H.

The direct method of mechanically graining porcelain enamel. ANON. *Ceram. Ind.*, **8** [6], 722 (1927).—A description of this method of graining is given. The following equipment is required: (1) a composition graining roller with grain molded on face, (2) a plate glass inking platen, (3) a composition rubber roll for spreading the graining oxide over the inking platen. F.P.H.

Permanent molds for iron casting. J. W. HINCHLEY. *Chem. and Ind.*, **46,** 423 (1927).—The great utility of permanent molds is pointed out, and the difficulties to be encountered are touched upon. The mold is made of 2 light hollow cast-iron molds, which are opened and closed by a toggle joint mechanism. The thickness and outer surface are designed so as to insure a proper rate of removal of heat after the metal is poured. The inner surface is coated with a refractory, hard enough to resist the cutting action of the molten metal, of such a nature that no gases are formed in contact with the metal, and of right thickness to transmit the heat at a safe rate. After a casting is removed, the mold is cleaned by an airblast of 200 lbs. per sq. in., and is then coated with a layer of carbon $\frac{1}{32}$ inch thick from an acetylene flame. The mold may be set on a travelling table, and the casting ejected automatically at the right moment. H.H.S.

Introduction to the fluorine question in enamel frits. P. EYER. *Keram. Rund.*, **34,** 294 (1926).—Various theories on the opacifying effect of fluorine in enamel frits are discussed. References are made to recent literature. (*Trans. Ceram. Soc.* [Eng.])

The use of opacifiers containing antimony in the enamel industry. H. HAUPT AND G. POPP. *Z. angew. Chem.*, **40,** 218–21 (1927).—A German opacifier "Leukonin" and an English "Timonox" are compared for their content of Sb_2O_3 and Sb_2O_5 solution in 1–3% tartaric acid, 3% KOH, 4% acetic acid, water, and apple and sauerkraut

juices. The Timonox shows much the higher solubility especially in its content of Sb_2O_3. Since Sb_2O_3 is more toxic than Sb_2O_5, Timonox is considered unsafe for use in enamel for cooking ware. Leukonin is safe to use. (*C. A.*)

Glass

The Baltimore and Ohio and the glass industry. ANON. *Amer. Glass Rev.*, **46** [34], 17 (1927).—In connection with the 100th anniversary of the Baltimore and Ohio, the history of its development is traced and its close relationship with the glass industry for the last half century is shown. E.J.V.

Sheet and plate glass industry makes rapid progress. J. W. CRUIKSHANK. *Amer. Glass Rev.*, **46** [35], 17–18 (1927); reprinted from *Chem. Met. Eng.*; see *Ceram. Abs.*, **6** [7], 267 (1927). E.J.V.

Recent progress in glass industry ably discussed by Prof. Turner. W. E. S. TURNER. *Amer. Glass Rev.*, **46** [37], 15–17 (1927); reprinted from *Pottery Gaz.*, **52** [599], 824–28 (1927); see also *Ceram. Abs.*, **6** [7], 270 (1927). E.J.V.

Elastic glass, its origin and applications. FRITZ POLLAK AND KURT RIPPER. *Diamant*, **48** [16], 307–308; [21], 403–406 (1926).—The properties of the authors' new colloid product, "Pollopas" are enumerated and discussed. Its index of refraction is 1.54 to 1.9, hardness 2.95, specific gravity 1.44, coefficient of thermal conductivity 0.00184, solubility in cold water for 24-hour treatment 0.1 – 0.2%. Various applications of the new product are enumerated. E.J.V.

Yellow glasses. W. H. *Diamant*, **48** [17], 328–29 (1926).—Mixes for various types of yellow glasses are given. A yellow carbon glass mix consists of 250 parts sand, 50 parts calcite, 100 parts soda, 2 parts wood charcoal, or with the use of silicon, 250 parts sand, 100 parts soda, 50 parts calcite, and 2.5 parts silicon. By replacement of the charcoal or silicon by about 6 parts sulphur or 2 parts boron or 5 to 6 parts calcium phosphide, a yellow glass is obtained. A nonactinic amber-yellow glass has the following batch composition: 62.37 sand, 3.11 potash, 23.13 soda, 9.35 lime, 1.24 saltpeter, 0.62 sodium uranate, and 0.18 antimony oxide. A greenish yellow iridescent uranium glass has the batch composition of 100 parts sand, 18 parts soda, 16 parts potash, 3 parts saltpeter, 15 parts calcite, 2 parts red lead, 1 part potassium bichromate, and 0.6 parts uranium oxide. The mix for golden yellow medicine bottle glass is 100 parts sand (with 2% iron oxide content), 6 parts soda, 26 parts sulphate, 35 parts common limestone, and 5 to 6 parts 85% pyrolusite. E.J.V.

The technique of mirror manufacture in the course of time. J. K. H. *Diamant*, **48** [18], 346–47; [19], 368–69 (1926).—A tracing of the history and development of mirror manufacture in Germany. The methods used in producing, polishing, and silvering mirrors are discussed. E.J.V.

Resistant glass. H. K. *Diamant*, **48** [20], 386–87 (1926).—Glasses which resist impact and pressure, and their applicability are discussed. A bottle glass with an alumina content of 8 to 10% into which phonolith was introduced during melting showed remarkable resistance to hammering when made into bottles with a 4 mm wall. A dark green glass of the type produced by K. had the following batch composition: silica sand 300 kg, soda 100 kg, barium carbonate 10 kg, barium nitrate 3 kg, phonolith meal 175.4 kg with 4.025 kg iron oxide, pyrolusite 12.5 kg, and uranium oxide 0.3 kg. The production of glasses of this type of other colors is discussed. E.J.V.

Artifices in the glazier's trade. ANON. *Diamant*, **48** [23], 443–44 (1926).—Artifices used in production of imitations of matt glass, raising the varnish marking on opal glass bulbs, decoration of glass ware by cementing on of a pearl embroidery, renewing of graduations, and others are explained. Methods of cleaning old stained glass are explained. Materials used for cleaning and polishing glass are enumerated. E.J.V.

Glazing with plate glass. ANON. *Diamant*, **48** [26], 508–509 (1926).—The superiority of plate glass over cylinder blown window glass in being entirely even, polished on both sides, uniformly strong, and having a clear, undistorted vision is discussed. Its use in various ways is taken up. E.J.V.

Glass sundials. Z. *Diamant*, **48** [28], 543–44 (1926).—A description of some old stained glass sundials dating back to the 16th century. E.J.V.

The glass bead industry in the Fichtel Mountains. J. KARL HOHENBERGER. *Diamant*, **48** [28], 545–47 (1926).—A history of this old phase of the glass industry in northeastern Bavaria. The equipment and methods used in the production of glass beads are discussed. E.J.V.

How does one detect a glass of inferior quality? W. PAULSEN. *Diamant*, **48** [29], 573–74 (1926).—By exposing a piece of glass to steam for 12 hours and then heating it rapidly just to the point of softening in a porcelain crucible one can detect glasses of inferior quality due to the fact that the surface shows a network of fine lines, sometimes to such an extent as to make it appear like a matt surface. E.J.V.

Mechanical production of glass by the Fourcault system. ANON. *Diamant*, **48** [29], 565–66; [30], 582–83 (1926).—A discussion of the growth of the use of the Fourcault system of glass production in Germany and central Europe. E.J.V.

The periodic plagues in the second half of the 14th century and their effect on the stained glass art. JOHN A. KNOWLES. *Diamant*, **48** [30], 583–85; [31],606–10 (1926).—A historical discussion of the English stained glass of the 14th century and producers thereof. E.J.V.

Production of mirror glass and mirrors. W. H. *Diamant*, **48** [32], 625–28 (1926).—Various methods and solutions used in the silvering of mirrors are given in detail. The decoration of mirrors with designs and methods of doing this are discussed. E.J.V.

Protection of workers and neighbors of glass etching plants. GUTMANN. *Diamant*, **48** [32], 628–30 (1926).—Methods used to protect the workers and the neighborhood from the bad effects of the hydrofluoric acid fumes generated in an etching bath by use of suction fans which draw the gas into a solution of milk of lime, and others, are explained. E.J.V.

A new window glass. ANON. *Diamant*, **48** [33], 650 (1926).—A note pertaining to "Vita Glass," which has a transmission of 65% of the ultra-violet rays of the sun. E.J.V.

Metallic reflections from glass. W. H. *Diamant*, **48** [33], 650–52 (1926).—The production of metallic lusters in glasses by firing glasses containing various metals under reducing conditions is described. E.J.V.

New stained glass productions. C. FRIES. *Diamant*, **48** [34], 668 (1926).—A description of 2 large stained glass windows produced by Erich Waske. E.J.V.

Western deposit of sodium sulphate now being developed commercially. ANON. *Glass Ind.*, **8** [6], 147–48 (1927).—A deposit of sodium sulphate in the Camp Verde Valley, near Prescott, Ariz., estimated to contain from 10,000,000 to 50,000,000 tons in that portion of the deposit now available, is being worked commercially by the Sodium Products Corporation. The sodium sulphate ore in its natural state is anhydrous and free from acid. An approximate production of 120 tons per day is reached. E.J.V.

Reports new glass with remarkable properties. W. F. KOHLER. *Glass Ind.*, **8** [6], 150 (1927).—A new heat-, pressure-, and acid-resisting glass which survives the test of being heated to 210°C in an oil bath and suddenly plunged into ice water, and withstands a pressure of 170 atmospheres has been developed in Europe. It resists any acid that may be applied to it. See also *Ceram. Abs.*, **6** [6], 251 (1927). E.J.V.

New glass plant for the Ukraine. ANON. *Glass Ind.*, **8** [6], 150(1927).—Arrangements have been completed for the construction of a $3,000,000 plant to be built at Kiev, in the Ukraine, using American production methods and equipped with $2,600,000 worth of equipment of which $1,200,000 worth will be purchased from American firms. The plant is to have an output of 22,000 metric tons of assorted glass per year. E.J.V.

Recent glass developments discussed by Geo. W. Morey. G. W. MOREY. *Nat. Glass Budget*, **43** [3], 21(1927); *Amer. Glass Rev.*, **46** [35], 15–16(1927); reprinted from *Chem. Met. Eng.*; see *Ceram. Abs.*, **6** [7], 267(1927). E.J.V.

Tapping tanks without accidents. ANON. *Ceram. Ind.*, **8** [6], 674(1927).—The method used at the Blackford Window Glass plant for tapping tanks is described. Directly in the rear of the tank house is a huge concrete basin filled with water, a specially prepared chute of fire brick runs from the floor of the drawing tank to the basin. The opening for the flow is made and the glass allowed to run into the water. The sudden contact with the water fractures the molten glass into a frit which renders it readily transportable and makes remelting considerably easier. F.P.H.

Composition of antique glasses. D. BERNARD NEUMANN. *Ceram. Ind.*, **8** [6], 681–83(1927).—A study is made of the chemical composition of antique glasses including coloring methods employed in ancient Egyptian glass manufacture. A history of the beginning of the industry is given. Tables showing the chemical composition of some of the early Egyptian glasses are given. F.P.H.

Advertising aids container men. ANON. *Ceram. Ind.*, **8** [6], 684–88(1927).—A report of the 8th annual meeting of Glass Containers Association of America. F.P.H.

Glass container art during past twenty-five years. H. L. HEINTZELMAN. *Chem. Met. Eng.*, **34,** 234(1927).—The 3 outstanding developments in the glass container industry during the last 25 years are the Owens bottle machine, suspended gob feeding, an improved type of annealing leer. M.E.M.

Yellow glasses. W. H. *Glas u. Apparat.*, **7,** 154(1926).—In general, glasses to be colored yellow by the addition of organic substances should be poor in alkali and rich in lime. J. Pelouze has observed that hydrogen colored glasses yellow at a red heat. He has concluded that only sulphate-containing glasses are colored yellow by the metalloids. An amber yellow glass batch for small pressed objects is 62.37% sand, and 3.11% potash, 23.13% soda, 9.35% lime, 1.24% saltpeter, 0.62% sodium uranate, and 0.18% antimony oxide. China yellow glasses are colored with sodium uranate, while Kaiser yellow glasses are colored with cadmium sulphide and are flashed. Iridescent uranium glasses have to be melted in a uniformly heated furnace from a batch containing only a small amount of lead, since lead-containing glasses colored with uranium normally are transparent. A suitable batch is 100 sand, 18 soda, 16 potash, 3 saltpeter, 15 limespar, 2 red lead, 1 potassium bichromate, and 0.6 uranium oxide. Great experience is necessary for the production of such greenish-yellow glasses. A batch for golden-yellow medicine glasses which do not foam consists of 100 sand with a content of 2% iron oxide, 6 soda, 26 saltcake, 35 ordinary limestone, and 5–6 of 85% pyrolusite. A sheet glass is made from the same batch but using 36 saltcake and 30 limestone. (*Jour. Soc. Glass Tech.*)

The drawing of glass tube and rod. H. PINK. *Glasind.*, **34,** 229(1926).—The mechanical production of tube and rod is discussed and the variables which govern the correct working of the machines. Illustrations of the Danner and Phillips machines are given. (*Jour. Soc. Glass Tech.*)

Possibilities in the development of glass as a working material. F. ECKERT. *Glasind.*, **34,** 491(1926).—E. considers the various attributes of glass which make it practi-

cally indispensable for certain purposes and compares glass with other materials, such as porcelain and the newly-developed organic urea "glasses," with a view to point out those directions in which the use of glass might be extended, and warning against directions in which it is threatened by other materials. The principal failing of glass is its brittleness and liability to fracture and yet in this it is not much inferior to porcelain. A promising range for future development is in electrical insulators, and in this connection since transparency is not essential, the range of raw materials which can be used might be considerably extended. Silica glasses, on account of their resistance to breakage and extraordinary resistance to sudden temperature changes, have a unique position, but can not compete with normal glasses on account of cost and difficulty of manufacture. New methods of research have already had considerable effect in improving the quality of certain glasses, and systematic research work will in time lead to further important developments. Metallic alloys have been greatly improved by after-heat treatment, and it is probable that a subsequent heat treatment of glass will improve its desirable and modify its undesirable properties if only sufficient information can be obtained. The question of improved working tools and molds calls for research. (*Jour. Soc. Glass Tech.*)

The advantages and disadvantages of various types of pot furnaces. S. Guss. *Glas-und Keram. Ind.*, **17,** Nos. 13, 14, and 19(1926).—Slit (German Bütten) furnaces give good bottom heat but a cutting flame. The Siemens slit furnace is unsuitable for working large hollow-ware, since the stack sucks the flames away from the working holes. A Siebert furnace of the newest type is found to have a greater fuel consumption when new than a Siemens slit furnace, probably because the Siemens furnace stack damper is kept nearly closed during working. The Siebert furnace stack damper is nearly full open during working, and the fireclay dampers to the constant exit flue softens and chokes up the flues. The Siebert furnace then requires less gas during glass-working periods; the waste gas escapes from the top of the working holes and is colorless. A disadvantage of the Siebert compared with the Siemens-slit type is that the regenerative chambers become very cold during working periods. Recuperative gas furnaces with built-in gas producers are variations of the slit type of furnace. Flames in slit furnaces still burn after reaching the exit ports. Knoblauch's "many flame" (Vielflammen) furnace is a new application of the slit furnace principle. With top flame furnaces, where the ports are situated well up the sides of the combustion chamber, no bottom heat is obtained and only soft glasses can be melted. Deep flame furnaces have not been fully tried out. In this type, the flame enters at the bottom of the furnace and does not rise above one-half the height of the pots. The best possible bottom heat is obtained, no cutting flame exists, and vessels of batch can be placed on a fireclay framework over the burners. Another way to avoid cutting flames is to slant the mixing chambers of the slit furnace. This shortens the path of the flame and necessitates putting the ports at the ends of the furnace, and the construction then becomes that of a deep-flame furnace. (*Jour. Soc. Glass Tech.*)

Glass pressing. C. J. Stahl. *Glashütte*, **55,** 903(1925); **56,** 353, 363, 383, 484, 503, 523, 543, 563, 583, 603, 623, 643, 663, 683(1926).—An article dealing with the production of glass jewelry, pendants, beads, and artificial precious stones, made from glass rods by heating and pressing. After a general historical introduction, S. deals with the factory producing this type of ware, the "pressing" furnace, molds, tongs, etc. Types of glass suitable for this kind of work and their preparation are also described. (*Jour. Soc. Glass Tech.*)

Temperature determinations in the glass industry. G. Gehlhoff and M. Thomas. *Glastech. Ber.*, **6,** 210(1926).—Optical and radiation pyrometers when in steady condition give the same temperature for all parts of the furnace (crown, walls, pot-edges, and glass

surface), which is the same as that indicated by a thermoelement in the crown. The pot furnace acts as a black body. The temperature of the glass itself is seldom stationary. In slit (Bütten) furnaces, the bottom of the pot is 10–30° hotter than the upper surface. In tanks, the bottom is found to be some 500° colder than the surface of the metal. While inequalities of temperature of the furnace rapidly disappear, the temperature of glass in pots is several hours (up to 5) in gaining equilibrium after melting ceases. The optically-measured temperature of the glass surface shows a mean value between the temperatures of the surface and the middle of the pot as measured by a thermoelement. At high temperatures glass in thin layers is thus permeable to the rays, but in thicker layers, particularly in connection with wall (pot) radiation, it is black. A simple and cheap substitute for an optical pyrometer consists in a carbon filament lamp, plugged in to the main and containing a variable resistance and simple voltmeter in the circuit. The lamp is suspended against a furnace opening and, to eliminate inhomogeneity of the filament, one portion only is used for comparison, this point being isolated by pasting on a black paper shield. At furnace temperatures, such a filament requires only about three-fourths of its full voltage. In the case of a 110-volt lamp, with practice, voltages to within $\pm\frac{1}{2}$ can be read, corresponding with limits of temperature error of $\pm 7°$. Excellent results are obtainable by the use of such a simple pyrometer when calibrated. (*Jour. Soc. Glass Tech.*)

An all-glass circulating pump for gases. F. Porter, D. C. Bardwell, and S. C. Lind. *Ind. Eng. Chem.*, **18,** 1086(1926).—The solenoid is actuated by an electric contact breaker 3 times per second, but the break is shorted by a 50 W lamp so that actually the current fluctuates between 0.5 and 0.3 amp. (roughly), causing the piston with an iron core (shown black) sealed in a glass tube to the top, to float up and down without actually striking the bottom of the cylinder; this being secured by proper adjustment of the position of the solenoid. Valves working in the usual manner complete the essentials. The pump described has a capacity of about 15 liters per hour against a head of 0.25 cm of water, but it will work against 20 times that head without losing more than 50% efficiency. The pump is claimed to be much superior to an elaboration of it described by Francis (*Fuel*, **5,** 39(1926)). (*Jour. Soc. Glass Tech.*)

Trial melts and furnaces in glass works. Anon. *Keram. Rund.*, **33,** 794(1925).—When introducing a new glass, it is necessary to make preliminary trial melts. Such experiments can be made in 3 ways, namely, (*a*) in a pot which otherwise would be in use, (*b*) in a pot reserved for such work, and (*c*) in a special trial furnace. In (*a*) such a procedure would be very expensive unless the glass could be utilized in some manner if the experiment were not a success from the original point of view. In (*b*) small pots were frequently set in a furnace for the purpose of making colored glass or opal for casing, and these could be used if required for experimental purposes. In neither case, however, is the method completely satisfactory, since the furnace conditions must remain suitable for the rest of the glass in the furnace. It is far better to have a special furnace for trial melts which can be run at any time as an independent unit and under any special conditions desired. Diagrams are given of furnaces recommended for the purpose. The first shows a recuperative oil-fired furnace for 2 glass pots to contain 200–250 kg of glass each. This can be constructed either with or without a glass-pocket. The second shows a tank furnace containing 2 small tanks each capable of holding about 250 kg of glass. It is constructed on the recuperative system and can be fired by oil or gas. The fuel required for melting an ordinary glass and keeping the heat during the working out is for the pot furnace 350–380 kg of oil or 600–650 cubic m of lighting gas; and for the tank furnace 280–300 kg of oil or 500–550 cubic m of gas. The 3rd diagram shows a small regenerative gas-fired furnace for 2 pots, which is recommended as better than either of the previous types since higher temperatures can be attained. Finally, a pot

furnace and tank furnace electrically heated are briefly described. (*Jour. Soc. Glass Tech.*)

Electric lamp bulbs. R. SCHMIDT. *Keram. Rund.*, **34,** 393(1926).—The total number of glass works and the number of bulb works in each of the various central, south, and north European countries are given. The evolution of the chemical composition of electric lamp bulbs in Germany from the time of their first manufacture is traced. No mention of magnesia is made. The essential properties of the glass for electric bulbs are enumerated. The following glass compositions are calculated from the corresponding batches and the linear coefficient of thermal expansion (α) is also given:

	Good Glasses					
	English crystal %	Rhenish crystal %	Tube glass %	New bulb glass %	Wartime bulb glass %	Bulb Glass containing BaO and ZnO %
SiO_2	54.0	57.0	58.1	61.5	60.0	63.0
PbO	34.5	31.0	29.4	23.6	11.8	15.5
BaO	——	——	——	——	11.4	4.0
CaO	——	——	——	——	1.7	——
ZnO	——	——	——	——	——	2.5
K_2O	9.2	8.0	3.0	5.3	7.0	4.7
Na_2O	2.3	4.0	9.4	8.8	8.1	10.2
Al_2O_3, Fe_2O_3	——	——	0.1	0.8	——	0.1
α	89.5	88.4	90.8	90.3	91.3	88.4×10^{-7}

Some typical poor compositions are also given. The following batches usually yield good bulb glasses:

Sand, purest	100	100	100	100
Red lead	37	15	22	13
Barium carbonate	—	13	10	10
Calcium carbonate	—	—	10	2
Zinc oxide	—	—	—	6
Calcined soda	25	27	20	32
Saltpeter	—	1	2	1.5
Calcined potash	14	15	20	9.0
Arsenic	0.4	0.25	0.3	0.5

Decolorizing material is added more to compensate for the iron from the pipes than that from the material. (*Jour. Soc. Glass Tech.*)

The rational utilization of heat in the glass industry. E. FELSNER. *Keram. Rund.*, **34,** 567, 587, 617, 637, and 649(1926).—The following fuel consumptions are obtained without special care for a 12-pot, 280 kg furnace from which crystal, medicine, colored, and thermos ware is made: 1.2 kg wood, 0.8 kg lignite or briquettes, and 0.6 kg coal per kg glass melted and annealed. In general, the consumption for continuous tank furnaces can be reduced by one-half to one-third of the above values. The following subjects are considered from a practical and nonmathematical aspect: gas-producers, lay-out, flues, recuperators, regenerators, pot-furnace chambers, operation of pot furnaces during melting, working, and holidays, and subsidiary furnaces, including leers. When designing a pot furnace, the number and size of the pots are fixed by the required daily output. The length of a rectangular furnace is fixed by the number of pots along one side and by allowing 5 cm between adjacent pots and between the end pots and the end walls. F. concludes that the correct proportioning of the dimensions of the various furnace parts plays an important rôle. No exact data are available and only main lines can be given. The foundation for the design of a pot furnace is the size of the combustion chamber, which is fixed by the daily output. An average size is 15 cubic meters, and for this size the following dimensions have been proved to be suitable.

The furnace produces on the average 7000 kg of glass per day. The fuel required, including subsidiary furnaces, is 4,500 kg of coal, 6000 kg of good lignite or briquettes, or 9000 kg of poor fuel such as earthly lignite, peat, etc. The gas producers should be capable of dealing with one-quarter more than those values. Their grate area can be calculated from the following average values:

Fuel	Blown producers	Slit producers	Step grate producers
Good	120 kg	70 kg	55 kg
Medium	150 "	100 "	70 "
Poor	200 "	125 "	95 "

The area of the combined gas and air ports, or of the port mixing chamber should be, for good fuels, 0.20 m², medium fuels, 0.22 m², poor fuels, 0.25 m². A free area through the recuperators or through the regenerator checker-work of 2½ times the port area have proved to be very good. The flues had to be at least as big as the ports. (*Jour. Soc. Glass Tech.*)

Iron and iron compounds as coloring materials for glass melts. E. FELSNER. *Keram. Rund.*, **34,** 818 (1926).—Different colored glasses are obtained according to the proportions of ferrous and of ferric compounds added to the batches, and according to the nature of the main batch constituents. For example, a wine-red glass with iron oxide can only be obtained with an all-soda batch, since the addition of potash to the batch increases the blue tint too much. Batches for more than 80 different tints of glass are given, classified under 10 kinds of main batches. When decolorizing glass, the proportions of selenium, nickel, and cobalt used should be adjusted according to the kind of iron compounds present in the raw materials. (*Jour. Soc. Glass Tech.*)

The internal frosted lamp. W. J. JONES. *Illuminating Eng.*, **19,** 269 (1926).—The method of frosting internally by spraying the interior with a strong solution of hydrofluoric acid, causes the glass to be brittle, apparently due to innumerable irregular little projections with many sharp angles. By subsequent treatment with another acid solution, these sharp edges are removed and the lamp is again strong and robust. Measurements have shown that 98% of the light emitted by the filament is available for use. (*Jour. Soc. Glass Tech.*)

Measurements of the thermophosphorescence of glass produced by radium emanation. R. E. NYSWANDER AND S. C. LIND. *Jour. Opt. Soc. Amer.*, **13,** 651 (1926).—Glass colored violet by previous exposure to radium emanation is heated in a small electric furnace into which is projected a tube carrying a sensitive thermopile. By swivelling this, the radiation from the walls and from the glass can be compared, but no heat radiation is found peculiar to the disappearance of the violet color of the glass at temperatures up to 510°, or that could be definitely ascribed to the phenomenon of thermophosphorescence. The visible light given out by the glass when heated to 115–255° is next measured by using a polarization photometer and a radium-zinc sulphide luminous paint as a standard for comparison. It is found that the curves intensity-time have equal areas (within $\pm 0.33\%$), showing that similar specimens of glass equally radiated emit the same total quantity of light when heated, whatever the rate. Curves showing the rate of decay of intensity of the radiation at 130° for glasses exposed to radiation 9 months and 3 years previous to these experiments show that there is probably a slow loss of thermophosphorescence at the ordinary temperature over very long periods of time. The velocity equations for first- and second-order reactions applied to the data give results suggesting that the second-order equation fit the facts better ($K = 0.00083$). The following are the values of K at the temperatures indicated: 120° $K = 0.00046$; 131° $K = 0.00074$; 145° $K = 0.00141$; 159° $K = 0.00263$. The van't Hoff equation $\log K = C - a/T$ when plotted is linear, and the graph of the data obtained above is also a straight line. (*Jour. Soc. Glass Tech.*)

Bone ash in opaque and ruby glasses. ANON. *Sprechsaal*, **59**, 442(1926).—Experiments were made to find the probable composition of bone ashes made under old works conditions, *i.e.*, in a pot-arch or annealing kiln, where the ash of the wood employed would quite likely become mixed with the bone ash and so provide fluxes as K_2O and Na_2O. Such bone ashes were found to contain up to 27.7% of organic matter and 3% of alkalis. One sample made with an insufficient air supply but containing no wood ashes had 16% of organic matter in it, and an old glassworks manager said that bone ash was always made for ruby glasses in this manner. The function of bone ash in old ruby glasses is mainly to reduce the gold or copper. Ruby glasses can be made without bone ash. For opaque glasses, bone ash is only used for luxury and antique ware, as better and quicker melting opaque glasses can now be made from cryolite and fluorspar batches in conjunction with feldspar and sodium fluosilicate. Zirconia is of doubtful value, since it is unstable above 1200°. Heavy lead glasses containing arsenic have been observed to become opaque. Calcium borate glasses in special circumstances become light bluish-white, but are expensive. Some successful bone ash batches for opal and opaline glasses are quoted. (*Jour. Soc. Glass Tech.*)

Sulphate as a refining material for alkali-lime glasses. L. BOCK. *Sprechsaal*, **59**, 633(1926).—It is known that the quality of sulphate glasses depends largely on the addition of the correct amount of carbon for reduction and that this is variable, depending on the oxidizing or reducing nature of the furnace gases. Best results are obtained when the amount added is such that a film of unreduced sulphate remains on the surface of the glass during the melting period, to be afterwards burnt off during the fining period. This film protects the glass from reducing gases and from soot during the melting period. Experiments undertaken to show that the addition of a small quantity of sulphate to a soda-ash batch ($\frac{1}{10}$ to $\frac{1}{12}$ of the amount of sodium carbonate) might be beneficial indicate that the soda ash entered into combination with the remaining batch materials, whereas the sulphate is not decomposed and remains floating on the surface of the glass as a protective film, which is gradually but completely dispelled during refining. This did not apply in the case of sulphate-containing alkali such as Leblanc soda, as in this case the sulphate is so intimately mixed with the alkali that it dissolves in and remains in solution in the glass to a great extent. The glasses made with Solvay soda ash and a small quantity of sulphate are plain and even throughout, colored slightly green through iron extracted from the pot walls, whereas glasses of similar composition but made with Leblanc soda are irregularly discolored for one-third of their depth. (*Jour. Soc. Glass Tech.*)

Recuperators or regenerators. H. BARTH. *Sprechsaal*, **59**, 664(1926).—A double recuperator of 19.53 cubic m content possesses a heating surface of 98.4 sq. m, while a regenerator having the same surface exposed to the gases is only 10.547 cubic m in volume. As compared with regenerators, recuperators possess the following advantages, (1) regularity and constancy of flame direction, (2) smaller cost of building for small furnaces, (3) saving of gas through elimination of reversals. Disadvantages are (1) sensitivity of the recuperator with regard to the maintaining of the capacity, particularly with irregular working, (2) dangers to the structure attendant thereon, (3) smaller heat recovery, (4) impossibility of reaching high temperatures, (5) difficulty and cost of repair. Regenerators are preferable when the highest temperatures are needed, when large furnaces are to be built, or when poor quality fuel only is available. (*Jour. Soc. Glass Tech.*)

An investigation of ring ruptures. G. GEHLHOFF AND M. THOMAS. *Sprechsaal*, **59**, 697(1926).—Rings are made by flashing, on a base glass having a coefficient of linear thermal expansion of 93.0×10^{-7}, glasses having the following coefficients $\times10^{-7}$: 93.6, 90.8, 90.6, 88.4, 86.2, 83.6, 95.3, 97.6, 98.7, and 103.0. When the expansion coefficient of the inner layer was larger than that of the outer layer, a compression ring

results; it is the inner layer that fractures, and with varying thicknesses of layers, shattering first occurs when the inner layer is thinner than the outer layer. To correct this fault, soda, potash, lime, or red lead can be added to the outer glass, or, conversely, sand or boric acid to the inner glass. When the expansion coefficient of the inner layer is less than that of the outer layer, a ring under tension "Sperrende Ring" results, the outer layer fractures, and with varying thicknesses shattering first occurs when the outer layer is the thinner. As a general rule, when it is not possible to make the expansion coefficients of the 2 layers just the same, it should be arranged that the thinner layer have the smaller coefficient of thermal expansion. Greater resistance to rupture is offered when the inner layer has the larger coefficient than *vice versa*, since it is then the inner layer that breaks, and this is of smaller diameter than the outer layer. (*Jour. Soc. Glass Tech.*)

Studies on some chemical and physical properties of lead glasses as functions of their compositions. H. KARMAUS. *Sprechsaal*, **59**, 725, 747, 768 (1926).—Glasses were prepared in liter-sized crucibles of clay specially resistant to lead glasses, *e.g.*, a glass intended to contain 78.73% PbO was found to contain, on the average, 78.43% PbO, and only 0.25% $Al_2O_3+Fe_2O_3$ from pot solution. The melts were stirred for 10 minutes with a water-cooled iron through which oxygen was blown, to avoid streaks and to oxidize any lead. The fundamental series of glasses corresponds with the formula $a(PbO, SiO_2) + (10-a)(K_2O, 6SiO_2) = S$, where a varies from 0 to 10 and is generally a whole number and S depends on the size of a. Seven other series were made, corresponding with formulas in which the expression in the last pair of brackets of the above formula was substituted successively by the expressions: $(Na_2O, 6SiO_2)$; $(0.5K_2O+0.5Na_2O, 6SiO_2)$; $(K_2O, 5.5SiO_2, 0.5Al_2O_3)$; $(K_2O, 5.8SiO_2, 0.2Al_2O_3)$; $(K_2O, 4SiO_2, 2B_2O_3)$; $(K_2O, 4SiO_2)$; $(K_2O, 8SiO_2)$. Two kinds of durability tests were carried out. Acid tests to find the tendency to "fleck" were done by the method of Heinrichs and Tepohl, the method being fully described. The resistance to water or "leaching test" was carried out by a method developed by Keppeler, and not published previously. Densities were determined on 20 to 30 g samples in air and water at 20° and corrected to 4°. Densities were also calculated from the densities of the individual silicates and their percentages. The refractive indices for the sodium line were measured by a Pulfrich refractometer with a measuring range up to $\mu_D = 1.730$, to an accuracy of 3 places of decimals. The conclusions drawn are: (1) The substitution molecularly of the total potash by soda has little effect on the tendency to fleck, but considerably reduces the leaching effect of water; when half of the potash is replaced by soda, the leaching effect of water is reduced by more than one-half the difference between the results for all potash and those for all soda. (2) The raising of the relative content of alkali causes both the tendency to fleck, and the leaching effect of water to increase rapidly. (3) The raising of the relative content of silica decreases somewhat the tendency to fleck, but decreases more so the leaching effect of water especially for low alkali glasses. (4) Partial replacement of the silica by alumina does not influence the tendency to fleck, but improves very considerably the resistance against water. (5) Partial replacement of the silica by boric acid increases enormously the tendency to fleck, and, in the case of some glasses, appreciably increases the leaching effect of water. (6) Keppeler's limits for the durability of lead glasses, namely $m(PbO, SiO_2)+n(R_2O, 6SiO_2)$ to $m(PbO, SiO_2)+n(R_2O, 8SiO_2)$ is proved to be essentially correct, as is also Zschimmer's lead glass rule for the maximum permissible potash content in potash-lead glasses. (7) Agreement between the found and the calculated densities is good. (8) Lichtenecker's logarithmic rule of mixtures can be used for the calculation of the optical properties of lead glasses. (9) From the results for the 2 physical properties, it follows that lead glasses consist of simple solutions of 2 components (silicates) one in another. (*Jour. Soc. Glass Tech.*)

Signal green glass and the light absorptions of various copper oxide-containing glasses. E. ZSCHIMMER. *Sprechsaal*, **59**, 818, 833, and 858 (1926).—Relevant literature and the conditions required by various marine authorities in Germany are reviewed. Melts and absorption experiments were made to discover the effects of several main batch constituents to which 4.5 parts of copper oxide and 0.8 to 2.0 parts of arsenious oxide were added per 100 parts of other batch constituents. Copper oxide allows a maximum transmission of light of the wave-length 500$\mu\mu$. The ratio of the amount of red light transmitted to the amount of green and blue is found to depend in a high measure on the general composition of the glass. The absorptions were measured and presented graphically by plotting the percentage transmissions against the corresponding wave-lengths of the light transmitted. The "relative transmission factors" for transmission of green and blue light compared with the transmission of red light were calculated for a constant transmission of 1% red light (including reflection losses) and for 2% red light. A soda-magnesia-silica glass gives the best relative transmission of blue and green light. Soda, in combination with lime or magnesia, gives better results than potash, but when in combination with lead, potash gives the best results. Alumina diminishes the relative transmission of blue light, and to a less extent of green light, in soda-lime-silica glasses. Boric acid diminishes considerably the relative transmission of green and blue light in the case of alkali-lime-silica glasses, and the substitution of lime by zinc has a similar effect. Further experiments to decide the important question as to the influences of chromium and cobalt in combination with copper are to be carried out. (*Jour. Soc. Glass Tech.*)

Infra-red absorption of didymium in glasses and in solutions. P. LUEG. *Z. Physik*, **39**, 391 (1926).—Measurements were made of the absorption in the infra-region of the spectra of 8 glasses made from various batches, each containing 0.55% Nd_2O_3, 0.31% Pr_2O_3, and 0.17% Sm_2O_3. The spectrometer used had a fluorspar prism having a base length of 5.5 cm and a refracting angle of 60°. The thickness of the glass test-pieces was so chosen that in each case the same number of didymium molecules lay in the path traversed by the light. The molecular composition of the glasses was as follows:

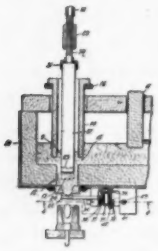
Glass	SiO_2	B_2O_3	As_2O_3	PbO	As_2O_3	CaO	K_2O
60	640	30	0.8			125	120
79	760		1.3			30	120
80	660	90	1.3			30	120
82	560		1.3	80			80
83	700	130	1.3		15		
84	450	90	1.3	80			80
87	400		1.3	140			45
100	390	260	1.3				

Glass	Na_2O	La_2O_3	Ce_2O_3	Nd_2O_3	Pr_2O_3	Sm_2O_3
60		1.8	0.9	1.0	0.6	0.3
79		1.8	0.9	1.0	0.6	0.3
80		1.8	0.9	1.0	0.6	0.3
82		1.8	0.9	1.0	0.6	0.3
83	100	1.8	0.9	1.0	0.6	0.3
84		1.8	0.9	1.0	0.6	0.3
87		1.8	0.9	1.0	0.6	0.3
100	100	1.8	0.9		0.6	0.3

Absorption curves were given for these glasses from 0.7 to 2μ, showing the influence of the batch on the absorption. Pronounced bands were found near the visible region and weaker bands near 1.5μ. These bands were ascribed to didymium, since pure optical glasses show no absorption in these regions. The lime glasses 60, 79, and 80

were distinguished by bands at 0.79 and 1.45μ, increase in lime content being accompanied by a diminution in the intensity of the bands. The diminution in absorption due to lime was also shown in glasses 80 and 84, which have the same boric acid content. The absorption curves for the lead-potash glasses showed that an increase in the lead content accompanied by a diminution in potash, as in glasses 82 and 87, produced an appreciable increase in the intensity but no change in the sharpness of the bands, such as were obtained in the visible region. Glass 87 had a strong maximum in the infra-red near the maxima of the borosilicate glasses, and the absorption curve assumed the character of that of the latter. In the series of glasses 60, 79, 80 and 82, there was a slight shift towards the longer wave-length side of the bands in the 1.5μ region. This shift was in the opposite direction from that found in the visible spectrum and could be explained by the increase in the intensity of the praseodymium band. Absorption curves were also given for liquid solutions of didymium, neodymium and praseodymium chloride and bands were obtained corresponding with those found in the spectra of the glasses. (*Jour. Soc. Glass Tech.*)

PATENTS



Apparatus for separating molten glass into mold charges. KARL E. PEILER. U. S. 1,629,409, May 17, 1927. In apparatus for segregating molten glass in mold charges, the combination of a container for the glass having a submerged discharge outlet, a member having a tubular end projecting into the glass in substantial alinement with the outlet and adjustable to different stationary positions, leaving a permanently open annular adjustable passage for the flow of glass to the outlet to regulate the weight of the mold charges, a plunger extending permanently past the passage for effecting the periodic discharge of the glass admitted through the passage, and means for reciprocating the plunger to move its lower end toward and from the outlet from a position below the passage.

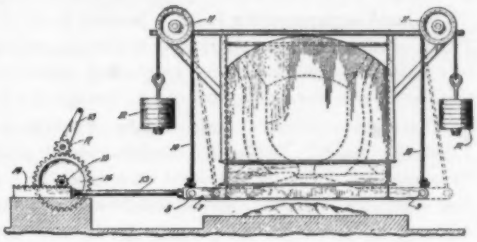
Glass-fabricating apparatus. WILLIAM J. MILLER. U. S. 1,629,455, May 17, 1927. In a machine for fabricating articles of glass, the combination of a movable mold support provided with an aperture for the downward discharge, therethrough of the fabricated article, a mold hingedly mounted on the support in such a manner that it may be inverted into registration with the aperture for discharging the article, means for inverting the mold after each fabricating operation, and means for returning the mold to its upright position before the next fabricating operation.

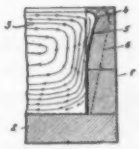
Glass composition. WARREN F. BLEECKER. U. S. 1,629,648, May 24, 1927. A transparent, henna colored lead glass resulting from a composition consisting of sand 75 parts, soda ash 80 parts, litharge 70 parts, borax 20 parts, niter 30 parts, and uranium oxide from 4 to 24 parts.

Glass-blowing machine. CLINTON S. BUDD. U. S. 1,629,653, May 24, 1927. Glass blowing apparatus comprising blowing elements disposed at a plurality of blowing stations, a plurality of blow molds, means for moving the molds to the stations in succession, and means for automatically and selectively preventing a blowing operation on certain of the molds at one of the stations.

Machine for finishing pressed-glass articles. RAYMOND T. KIMBLE. U. S. 1,629,827, May 24, 1927. In a fire-finishing and polishing machine for articles of glassware, a rotary table, means for continuously rotating the table, ware supports borne by the table, a furnace for reheating the ware during the advance travel of the latter, a repressing die and automatic means for reciprocating the die into coöperative relation to the successively advancing supports for repressing the reheated articles, and means for fire-finishing the repressed ware in the further travel of the table.

Pouring device for glass furnaces. ARTHUR HOWE CARPENTER AND PHILIP C. HUNTLEY. U. S. 1,630,829, May 31, 1927. A glass furnace chamber having a short downwardly extending spout of comparatively large cross-sectional area, one side of the spout being inclined and the opposite side, at the upper end of the spout, extending inwardly to a vertical plane not far distant from the lower end of the first-mentioned side.





Tank block for glass furnaces. JAMES L. CRAWFORD. U. S. 1,630,892, May 31, 1927. A block for glass melting tanks having an outwardly inclined corrugated face.

Apparatus for controlling the flow of molten glass through a discharge aperture. CARL HENRY RANKIN. U. S. 1,631,061, May 31, 1927. In apparatus for controlling the flow of molten glass through a discharge aperture, a liner having the discharge aperture formed therein, corrugations on the interior wall of the aperture, a plunger arranged in axial alinement with the aperture, a sleeve arranged coaxially with the plunger to inclose an annular space around the plunger and corrugations on the interior wall of the sleeve.

Glass-drawing apparatus. RAYMOND D. HURLEY AND BROOKE H. PATTON. U. S. 1,631,097, May 31, 1927. A glass drawing apparatus comprising means for establishing a pool of molten glass, guides arranged vertically over the pool means and subject to the heat thereof, a bait supporting carriage vertically movable between the guides, and means for lubricating each of the guides comprising a lubricant pocket associated with the upper end thereof in such manner as to receive heat therefrom by conduction, the lubricant pocket having a conduit leading to the carriage-engaged surface of the guide.

Feeding molten glass. KARL E. PEILER. U. S. 1,631,107, May 31, 1927. The method of shaping the lower ends of a succession of mold charges of molten glass delivered downwardly through an outlet from a container, which compresses periodically causing glass below and adjacent to the outlet to move upwardly, thrusting oppositely directed shear blades through the upwardly moving glass and immediately withdrawing the blades, whereby the shape imparted to the glass remaining above the shear blades, after the severing operation, is retained as the shape of the lower end of the next succeeding mold charge.

Glass-drawing apparatus. WALTER G. KOUPAL AND JOSEPH S. GREGORIUS. U. S. 1,631,138, June 1, 1927. The combination with apparatus arranged to draw a glass sheet from an open pool of molten glass, of means for preventing inward movement of the edge of the sheet in the pool, comprising a shielding bowl above the glass, but closely adjacent thereto, and having a slot extending inward from its edge and fitting around the edge of the sheet, cooling means for the bowl, and reflecting members projecting outward from the bowl on each side of the slot.

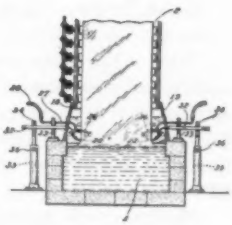
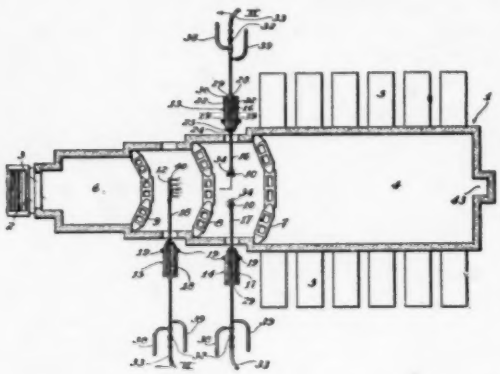


Plate-glass surfacing car. ALFRED L. HARRINGTON. U. S. 1,631,126, June 1, 1927. In combination with a pair of abutting cars having means for locking them together, of means for maintaining the top surfaces of the abutting ends flush, which comprises

a plate or member on each car on each side thereof projecting forwardly and engaging a downwardly facing surface on the other car.

Control apparatus for leers. JOSEPH CARL PARKINSON. U. S. 1,631,151, June 7, 1927. In combination with a tunnel leer, conduit means lying in the outlet end of the leer and directed longitudinally thereof, and blower means connected therewith and arranged so as to cause a flow of air through the conduit in either direction.

Plate-glass transfer and laying apparatus. HALBERT K. HITCHCOCK. U. S. 1,631,203, June 7, 1927. In combination in apparatus for transferring glass sheets from one car or carrier mounted on a track to another car or carrier on a parallel track and turning them over, which comprises a vacuum lifting frame mounted for vertical movement over each track, and a turnover frame mounted for lateral movement between the 2 frames, and adapted in its 2 extremes of movement to lie beneath said frames.

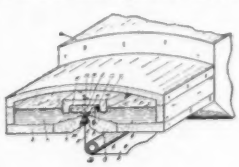


Process and apparatus for melting glass. HALBERT K. HITCHCOCK. U. S. 1,631,204, June 7, 1927. In a glass melting tank, having a top wall or arch, a melting end, a delivery end remote therefrom, a cooling section intermediate the ends, means for applying heat to the melting end to reduce the batch supplied thereto, and means for spraying a cooling fluid into the space between the glass bath and the arch in the cooling section.

Apparatus for drawing sheet glass. JOSEPH S. GREGORIUS. U. S. 1,631,319, June 7, 1927. In combination in apparatus for drawing sheet glass, a glass drawing tank adapted to carry a bath of molten glass from which a sheet is to be drawn, means for drawing a sheet of glass upward from the bath with its plane of generation lying transversely of the bath, and a clay bar lying beneath the surface of the glass in alinement with the line of generation of the sheet, and provided with a central longitudinal rib, and with a slot extending through the bar on each side of the rib and parallel thereto.

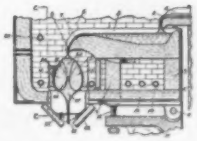
Glass-forming apparatus. ORIN A. HANFORD. U. S. 1,631,633, June 7, 1927. In a device for forming hollow glass articles the combination of a mold and a bottom plate, the bottom plate having a molding surface of plaster of Paris.

Glass feeder. LEONARD D. SOUBIER. U. S. 1,631,230, June 7, 1927. The combination of a container for molten glass, a cylindrical member extending upward from the floor of the container, and providing an open passageway for the discharge of glass, a regulator positioned in the glass above the member, the regulator having an annular extension or wall projecting downward and surrounding the member and spaced therefrom to provide a restricted annular passageway by which the glass enters the member, and automatic means for periodically moving the regulator up and down.

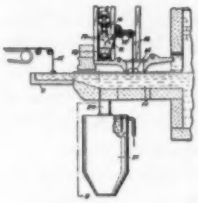


Method and apparatus for producing sheet glass. ENOCH T. FERNGREN. U. S. 1,631,804, June 7, 1927. In the method of producing sheet glass by moving the glass downwardly through an orifice in the molten-glass container, that step wherein the surface portion of the molten glass directly overlying the

orifice is isolated from the main body of glass and an increased surface tension is created in this isolated section, by providing spaced clinging surfaces to which the edges of the isolated body of glass may adhere.



Drawing sheet glass. ENOCH T. FERNGREN. U. S. 1,631,805, June 7, 1927. In an apparatus for producing sheet glass, a pair of similar directing members between and around which molten glass flows to form the sheet, the members varying in cross-section symmetrically from their centers toward each end thereof.



Method and means for skimming glass. WARREN A. RHOADES. U. S. 1,631,759, June 7, 1927. The process of producing sheet glass, consisting in providing a mass of molten glass, skimming the molten glass by drawing the surface therefrom in sheet form, and then drawing a sheet from the skimmed glass.

Glass for electric insulating purposes. Brit. 254,174, Nov. 24, 1925. A glass to be used for electric insulation purposes, particularly for the parts of electric lamps, contains both potash and soda, and the ratio of potassium oxide to sodium oxide in the glass is within the limits of 7 : 1 and 3 : 1. The percentage composition of a suitable glass is $SiO_2$65, K_2O12, Na_2O3, and PbO20. Another glass has the percentage composition $SiO_2$70, K_2O8, Na_2O2, $B_2O_3$10, and BaO10. Specifications 15,963/08 and 219,972 are referred to. A further specification (Brit. 254,175, Nov. 24, 1925), is for a glass containing lead oxide and at least 2% of calcium oxide. A glass suitable for parts of electric lamps has the following percentage composition: $SiO_2$62, Na_2O7, K_2O8, PbO20, and CaO3. (*Jour. Soc. Glass Tech.*)

Glass for electric insulation. Brit. 256,188, June 10, 1926. Electric insulators are formed from glass which has been devitrified. A further specification (Brit. 256,189, June 11, 1926), other particulars same as above, refers to glasses suitable for electric insulation purposes which contain, in addition to silica and calcium oxide, at least one oxide of a divalent or trivalent metal, iron oxide being used as a flux. A suitable glass has the following percentage composition: $SiO_2$67, K_2O3, CaO10, BaO10, $Fe_2O_3$10. (*Jour. Soc. Glass Tech.*)

Ultra-violet ray absorbing glass. Chance Bros. and Co., Ltd., P. V. W. GELL, C. E. GOULD, W. M. HAMPTON, H. S. MARTIN. Brit. 256,737, June 5, 1925. A colorless glass for absorbing ultra-violet rays contains an ingredient which will absorb the rays but will color the glass, and a second ingredient also efficient in absorbing the rays, which has the property of neutralizing the color imparted to the glass by the first ingredient. In making Crookes glass containing cerium, the yellow color imparted to the glass by the cerium is neutralized by adding didymium. The proportion of cerium in the batch may be about 3.5% and that of didymium about 0.7%. (*Jour. Soc. Glass Tech.*)

Glass containing barium. RHENANIA-KUNHEIM VEREIN CHEMISCHER FABRIKEN A. G. Brit. 259,953, Oct. 8, 1926. Barium silicate, produced by heating a mixture of 100 parts of finely ground heavy feldspar and 13 parts of quartz sand in a revolving furnace at about 1200° with the introduction of steam, is used as a batch material; *e.g.*, 100 parts of sand, 26 parts of calcined soda, 15 parts of calcium carbonate, and 34 parts of barium silicate. (*Trans. Ceram. Soc.* [Eng.])

Molding silica. L. B. MILLER. Brit. 262,110, Nov. 23, 1926. Silica is rendered plastic by heating at 1700°, and a molding member of carbonaceous material at approximately the same temperature is introduced into the mass. To prevent chemical action between the silica and the mold these are removed and cooled rapidly in the air, thereby facilitating the removal of the mold from the solidified silica (*Brit. C. A.*)

Glass transparent to ultra-violet rays. R. HADDAN. Brit. 263,410, July 1, 1926. To produce sheets 4 mm thick, which are transparent to ultra-violet rays, the iron impurities in the raw materials are reduced to less than 0.055% and the materials are melted under nonoxidizing conditions. The titanium content is also reduced by subjecting the material, before the final setting, to reducing conditions. A reducing agent, sugar or powdered Carborundum, is melted with a calcium phosphate glass.
(*Trans. Ceram. Soc.* [Eng.])

Treatment of silica articles. E. HERZOG. Brit. 264,863, Jan. 21, 1927. Articles of vitreous silica, having a rough surface which is to be glazed, are mounted so that they can be rotated and heated in an enclosed space at about 1000°, which is well below the softening temperature, but sufficiently high to prevent cracking during the subsequent process. The articles are then subjected to a fusing temperature from the flames of suitably arranged burners, the region of fusing heat being continuously changed by rotating the article and traversing the burners until the whole surface is glazed.
(*Brit. C. A.*)

Heavy Clay Products

Flashing and other unique developments in connection with a modern tunnel kiln face brick plant. J. T. ROBSON AND F. M. HARTFORD. *Jour. Amer. Ceram. Soc.*, **10** [7], 487–92 (1927).—A few of the salient features uncommon in ordinary face brick plant design are brought out. Many of these are rendered necessary by the use of a tunnel kiln for firing. Details of plant layout, screen arrangement, method of introducing barium carbonate to the pug mill, the drier which is a combination of the waste heat and radiated heat types, and kiln design and operation are given.

The decay of modern brickwork. A. P. LAURIE. *Brit. Clay-Worker*, **35** [417], 280 (1927).—All modern brickwork is exposed to the attack of sulphur acids due to the burning of sulphur in coal which now extends far beyond our cities. The sulphur acids attack the mortar or cement, forming deadly sulphate of lime, which, if it passes into the brick will crystallize there and produce rapid decay. Facing brick due to porous structure are peculiarly susceptible to this danger, and should only be pointed with a fat lime mortar with plenty of sand R.A.H.

Colors in clays. ANON. *Brit. Clay-Worker*, **35** [419], 328–29 (1927).—The causes of some colors in both raw and fired clays are given. Color is no criterion of quality of clay. Too little attention is given to gases formed in kiln during firing which are doubtless the cause of color variation in some materials. R.A.H.

Good brick from a good plant. ANON. *Brick Clay Rec.*, **70** [11], 847–55 (1927).—A description of the plant of the Wyandot Clay Products Co. F.P.H.

Better methods mean lower costs. ANON. *Brick Clay Rec.*, **70** [12], 922–23 (1927).—A report of the spring meeting of the Ohio Ceramic Industries Association at Columbus, May 26 and 27, 1927. The following papers were read and discussed: "Protecting Ohio Ceramic Industries," by President Murphy; "What the Engineering Experiment Station Should Be Doing for the Industries of Ohio," by E. A. Hitchcock; "The Business Outlook," by C. H. Chase; "Modernization in Industrial Processes," by John Younger; "Modernization and Profits in Heavy Clay Products," by F. M. Hartford; and "Modernization in Clay Mining in Ohio," a symposium led by H. E. Nold. E.J.V.

How a Yankee plant makes brick. ANON. *Brick Clay Rec.*, **70** [12], 936–37 (1927).—A description of various interesting features which can be seen at the Montowese Brick Co., North Haven, Conn. E.J.V.

The effect of water content and pressure of repressing on the porosity of stiff mud brick. S. M. PHELPS. *Amer. Refrac. Inst. Tech. Bull.*, 11 (1927).—Determinations made on materials submitted by 3 plants were as follows: (*a*) per cent water in the various muds; (*b*) per cent porosity of the green brick from the column and after various

pressures of repressing; (*c*) per cent porosity of green materials after compressing the wet mix in the hydraulic press; (*d*) volume firing shrinkage of various samples when heated to 1400°C in 4 hours and held at this temperature for 5 hours (reheat test); (*e*) same as (*d*), when fired in a commercial firebrick kiln to cone 11; (*f*) per cent porosity after commercial firing. The results show the difference in water content of the softest and stiffest muds to be not more than about 2%, which difference has little effect upon the resulting porosity; repressing reduces porosity appreciably, especially when maximum pressures are used; densest brick are made from the driest clay mixture, repressed with maximum repress pressure. Erroneous results were obtained from the laboratory firing and the results of such comparatively rapid heat treatments should be used with great caution. E.J.V.

Manufacture of "Kraf-Tex" and "Mello-Tones." ANON. *Clay-Worker*, **87** [6], 445–48(1927).—A description of the plant and products of the Corinth Brick Co. F.P.H.

Vitrified clay products vs. concrete products. ANON. *Clay-Worker*, **87** [6], 450–53(1927).—A few pointers relative to the merits of various materials used in sewer and underdrainage construction are given. The disintegration of concrete by alkali is discussed. F.P.H.

Factory design and equipment. T. W. GARVE. *Clay-Worker*, **87** [6], 454–57(1927). —The 3rd of a series of articles on this subject. This article deals with the handling and storing of raw materials. See *Ceram. Abs.*, **6** [5], 175, [6], 222(1927). F.P.H.

Sewer pipe manufacture in Old Virginia. C. C. LAMOND, JR. *Clay-Worker*, **87** [6], 470–72(1927).—A description of the plant of the Potomac Clay Works. F.P.H.

An oversold twenty-four hour plant. ANON. *Clay-Worker*, **87** [7], 525–32(1927).—A little of the history of Fiske & Co., Inc., is given. The Darlington, Pa., plant of this company, originally built to produce 36,000 brick per day, has had its production more than doubled by the addition of a Harrop tunnel kiln to the 7 periodic kilns originally built. Though running on a 24-hour basis and producing over 1,800,000 brick per month, the plant is still running behind on orders. A detailed description of the plant and its equipment is given. E.J.V.

Factory design and equipment. T. W. GARVE. *Clay-Worker*, **87** [7], 534–40(1927). —The 4th of a series of articles on this subject. The reduction of raw materials is dealt with. Detailed discussions of friability, crushing, and grinding and pulverizing are presented. Various types of equipment used for these purposes are described. See *Ceram. Abs.*, **6** [3], 163; [5], 175; [6], 222(1927). E.J.V.

Mechanical introduction of barium to clay bodies. MARION W. BLAIR. *Clay-Worker*, **87** [7], 555–56(1926); reprinted from *Jour. Amer. Ceram. Soc.*, **10** [6], 464–66 (1927); see also *Ceram. Abs.*, **6** [7], 282(1927). E.J.V.

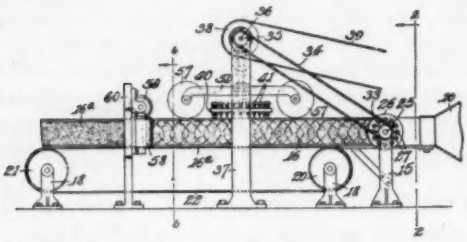
PATENTS

Drying tile. CHARLES B. CUSHWA. U. S. 1,629,151, May 17, 1927. A drying board, comprising a substantially circular supporting member having a central opening therethrough and providing a substantially continuous ring, and a stiffening flange on the supporting member, the flange being integral with the supporting member and extending all around the same in a substantially uninterrupted manner.

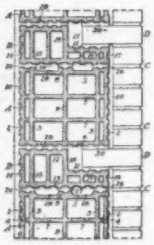
Brick die. JESSE C. MARTIN, JR. U. S. 1,630,066, May 24, 1927. A brick die having a recess for the formation of a boss upon a brick, a collapsible bottom for the

recess and means to press the bottom into the recess for separation of the formed brick from the die surfaces.

Apparatus for scarifying plastic-clay columns. JOSEPH B. NICHOLSON. U. S. 1,631,220, June 7, 1927. In a scarifying apparatus, a scarifying device, a shaft for rotating the scarifying device, means for securing the scarifying device to the shaft for rotation therewith, the means permitting longitudinal movement of the scarifying device on the shaft, and means whereby the scarifying device is maintained at a fixed distance from the adjacent surface of a traveling clay column upon which it acts.



Wall construction. ROBERT G. WALLACE. U. S. 1,631,659, June 7, 1927. A composite wall comprising a brick facing on the outer face thereof, formed of a plurality of stretcher courses between spaced header courses, and a backing formed of alternate courses of hollow main and header tiles, the header tiles having recesses into which the inner portions of the header brick of the facing extend, there being a web in each tile in close proximity to and parallel with the outer wall of each tile, at the inner face of the wall structure and sufficiently close to the outer walls of the tiles and the inner plane of the wall, that if the outer walls of some of the tiles spall off, the load bearing portions of the tiles from the webs of the spalled tiles to the faces of the tiles adjacent to the brick facing will be of sufficient strength to support the load for which the wall was designed.



Refractories

Refractories in the zinc industry. ANON. *Brit. Clay-Worker*, **35** [418], 302 (1927).—Experiments have demonstrated the advisability of using in retorts or muffles in the distillation of zinc a bonding clay low in metallic oxides (other than alumina) and at the same time devoid of free silica in the case of the ore being basic. When the ore in use is siliceous a little free silica is no disadvantage. Grog should be made of calcined flint clay rather than ground up discarded zinc retorts which contain a high percentage of zinc spinel. R.A.H.

Clays for glass-house pots. ANON. *Brit. Clay-Worker*, **35** [418], 303 (1927).—Clay suitable for glass-house pots requires to be of such a composition as will render it capable of resisting a high temperature without softening and without becoming friable when hot. Most satisfactory results obtained by using a mixture of different fire clays; the most refractory contains the largest amount of silica and the minimum of iron oxides. Soda and potash decrease refractoriness. The bond clay should be fat, aluminous, of low sintering point, and finely ground. The base clay should be a highly aluminous refractory free from pyrite. Grog should be made of selected clay rather than fire brick. Two examples of glass pot mixtures are given together with chemical analysis. R.A.H.

Fire brick for glass works. ANON. *Brit. Clay-Worker*, **35** [419], 331 (1927).—Brick used in furnaces or tanks in which glass is melted if preheated for several hours at 1400°C or higher previous to using have an entirely different character from those heated in the ordinary manner by the glass manufacturer. They become uniformly vitrified and more resistant to the glass melted in a tank built from such brick. G. V.

Wilson of the Scottish Geological Survey showed that the well vitrified and properly heated brickwork taken from a glass tank contained a large proportion of crystalline mullite: a material singularly resistant to corrosion by glass and largely insoluble in hydrofluoric acid. Mullite crystals convert from the clay slowly at 1150°C, but fairly rapidly at 1400°C. Saltcoats clay of Scotland contains almost exactly the proper proportions of alumina and silica to form mullite and spherulites up to $\frac{1}{4}$ inch in diameter composed wholly of mullite are readily produced in such quantities to occupy the bulk of the clayey mass. The melting point of mullite crystals is 1816°C and readily recrystallizes from a fused solution. Siliceous clays are not suitable for use in glass melting pots or tanks as they never become fully saturated with alkali or lime, but form readily fusible silicates which drop off and the brick is thus eaten away. R.A.H.

The corrosion of fire brick. ANON. *Brit. Clay-Worker*, **36** [420], 20(1927).—A review of the causes of corrosion of fire brick while in service and properties desirable in fire brick to aid in their resistance to corrosion. R.A.H.

Brick for electric brass-melting furnaces. ANON. *Brit. Clay-Worker*, **36** [421], 37(1927).—Three types of electric furnaces used for melting brass and similar alloys: (1) those with a granular resistor, (2) those with a moving indirect arc, and (3) induction furnace. (1) has a hearth made of a mixture of fire clay and bauxite; (2) an asbestos-fireclay cement, a highly aluminous cement or Carborundum with small amount of fire clay; and (3) a rammed mixture of fire clay, asbestos, and broken fire brick. There is a great scope for the production of a refractory material which is unaffected by the molten material. A discussion of some available materials for this purpose is given. R.A.H.

The refractory materials of South Wales. W. R. D. JONES. *Brit. Clay-Worker*, **36** [421], 55–59(1927).—J. states refractoriness, although of great importance is no criterion of the value of furnace linings. A property of refractories which has not received the attention it deserves is texture (grain compactness as a whole) and the setting of bricks in furnaces according to suitability with reference to this property. The properties of silica brick are antagonistic resulting in the sacrifice of one property for another. The chemical analysis of materials from S. Wales used for making silica brick averages 95% SiO_2, 0.2 to 1.5% Al_2O_3, less than 1% Fe_2O_3. Petrographically they are fine-grained and light buff color, with angular quartz grains and some slightly micaceous. On heating, quartz undergoes 2 expansions, (1) temporary, and (2) permanent (formation of tridymite and cristobalite). Conversion of quartz proceeds fairly rapidly at first (about 75% of total) and then slows down. Data are given which show that conversion takes place more rapidly: (1) the finer the texture, (2) the greater the amount of nonsiliceous matter, (3) the longer the material is exposed to temperature. Other subjects covered are hearth sands, silica mortar and cement, fire clay, and dolomite with analyses of the latter 2 included. J. states dolomite rock should conform to following conditions to be a suitable source for basic smelting purposes: (1) silica should be less than 2%; (2) chemical composition should be constant over areas sufficiently large to give an extensive supply of the material; (3) the proportion of $MgCO_3$ should be as near as possible that of dolomite, *i.e.*, 45%; (4) it should be firm and compact and not easily weathered. R.A.H.

Thermal expansion of graphite. P. HIDNERT AND W. T. SWEENEY. Bur. Stand., *Tech. Paper*, No. 335.—This paper gives the results of an investigation on the thermal expansion of longitudinal and transverse sections of artificial graphite electrode over various temperature ranges between room temperature and 600°C. A summary of available data by previous observers on the thermal expansion of graphite (natural and artificial) and of other forms of carbon is included. In this investigation the coefficients of expansion of graphite were found to be low. The transverse samples expand con-

siderably more than the longitudinal samples. For both the longitudinal and transverse samples the coefficients of expansion decrease slightly as the purity increases. The table in the summary gives a résumé of average coefficients of expansion derived from the data on all samples for various temperature ranges between 20 and 600°C. R.A.H.

Fundamental qualities of some refractory clays. ANON. Bur. Stand., *Tech. News Bull.*, No. 121, p. 5 (1927).—A study of the elasticity, transverse strength, and thermal expansion of 4 fire clays at room temperature and at 550°C. A table is included which gives values for these properties, as well as maximum elongation values, for specimens of clay which had been fired to cone 12, and also specimens consisting of 50% clay and 50% grog of the same clay fired to cone 15. A discussion relative to the effect of these properties on the spalling behavior of refractories follows. R.A.H.

The firing and cooling of silica brick in a tunnel kiln. J. GREWE. *Feuerfest*, **3** [4], 53–54 (1927).—A description of a tunnel kiln suitable for firing silica brick. F.P.H.

More research for refractories. ANON. *Ceram. Ind.*, **8** [6], 692–94 (1927).—A report of the 3rd annual meeting of the American Refractories Institute. Mullite, the obsolescence problem, more generous support of research by the industry, and greater efficiency in the education of refractories-ceramists were a few of the outstanding topics discussed at this meeting. The following papers are abstracted: (1) "Some Characteristics of Fire Clays and Brick Made from Them," by R. F. Geller; (2) "Properties of Clay Refractories Resulting from Control of Grain Size of the Flint Clay," by S. M. Phelps; (3) "Effect of Purite on Refractories," by G. S. Evans; (4) "Symposium on Mullite"; (5) Discussion of the ceramic engineer's training by several members. Similar article in *Brick Clay Rec.*, **70** [11], 856–57 (1927). F.P.H.

Thermal expansion of clays and special refractories. ANON. *Ceram. Ind.*, **8** [6], 696 (1927).—The report of the Bureau of Standards on the following materials investigated: (1) foreign and domestic magnesite, (2) diaspor, (3) Indian, Grecian, African, Turkish, and Cuban chrome ore, (4) alumina, (5) artificial corundum, (6) cyanite, (7) silicon carbide, (8) zirconium silicate, (9) specimens of 13 brands of fire brick from the principal producing districts of the country, (10) three brands of commercial silica brick, (11) specimens of foreign and domestic kaolin and ball clay. F.P.H.

Bureau of Standards studies slagging of refractories. ANON. *Ceram. Ind.*, **8** [6], 696 (1927).—A study was made of the deformation behavior of various mixtures falling within the composition tetrahedron of which the following phases are the apices: (1) anorthite, (2) mullite, (3) silica, (4) magnetite. Under oxidizing conditions a eutectic of the following composition was found: 10% Fe_2O_3, 8% CaO, 15% Al_2O_3, 67% SiO_2. F.P.H.

The testing of refractory material. E. H. SCHULZ. *Tonind. Ztg.*, **50** [50th Anniv. No.], 38–40 (1926).—The principal use of refractories in Germany is in the steel plants. About 80% of this product goes to the iron industry. About 6 million tons of Martin steel were produced in 1926 and 150,000 tons of refractories were required for this purpose. The establishment of requirements that the different refractories must meet in order to be of service is discussed. F.P.H.

Refractory lining of the rotary kiln. G. MARTIN. *Zement*, No. 12, 226 (1927); *Rock Prod.*, **30** [10], 92 (1927).—A report on this subject was recently submitted by Geoffrey Martin at the convention of the Refractory Materials Section of the British Ceramic Society, held in Leeds. As an example, a rotary kiln was selected, with the following dimensions: length 200 ft., diameter, 9 ft., diameter in sintering zone about 10 ft. The following data were established for this kiln: The lining lasts 3 weeks to 9 months, depending on the skill of the operator. To prevent corrosion of the lining by strongly alkaline substances, the slury is allowed to pass through the kiln without

great heat when the kiln is being started, so that a coating is gradually formed on the refractories, which becomes strongly cemented to the latter at higher temperatures. Though little information is available the opinion prevails that products with high alumina content are best suited for linings. Thus bauxite blocks have shown but one inch wear after 12 months. Satisfactory results were obtained with a clinker concrete, mixed in the proportions of 1 part cement to 2 parts clinker, which, however, must be replaced after every interruption of operation. They may be then ground and used as cement. The table below lists the reactions, temperatures, and length of the zones in the rotary kiln discussed above. Suitable refractories for the different zones are specified.

Reaction in zone	Temp. °C	Kiln section in ft. from feed end	Refractories to be used
Drying of raw material	427–82°	60–70	Ordinary refractories strong, nonporous, 4½ in. thick
Preheating chemically combined H_2O of clay is driven off	up to 815°	30 ft. long	As in drier, 6 in. thick
CO_2 is driven off	815–1315°	50 ft. long	Good refractories, low in silica 6 in. thick (31–33% Al_2O_3, 62% SiO_2, 3–4% Fe_2O_3, .5% CaO)
Clinkering	1315–1425°	40 ft. long	Lining 9 in. thick (33–43% Al_2O_3, 49–58% SiO_2, 3–4% Fe_2O_3 .7% CaO)

Manufacturing refractories in India. W. H. BATES. *Brick Clay Rec.*, **70** [11], 859–60(1927). F.P.H.

Fundamental qualities of some refractory clays. ANON. *Brick Clay Rec.*, **70** [12], 930(1927); reprinted from *Tech. News Bull.*—Studies of elasticity, transverse strength, and thermal expansion of 4 clays at room temperature and at 550°C have been made. Results are given in the following table:

		Modulus of rupture		Modulus of elasticity*		Maximum elongation†		Linear thermal expansion 20° to 550°C
		Cold	550°C	Cold	550°C	Cold	550°C	
		lb/in²	lb/in²	lb/in²	lb/in²	%	%	%
Mo. semiflint	A	3000	2100	68	63	0.04	0.03	0.48
	B	3000	3000	57	59	0.05	0.05	0.46
Pa. semiflint	A	1200	1500	36	41	0.03	0.04	0.25
	B	650	650	14	16	0.05	0.04	0.22
Flint	A	200	—	3	—	0.07	—	0.39
	B	120	130	3	4	0.04	0.03	—
Ky. semiflint	A	980	1600	23	32	0.04	0.05	0.39
	B	560	700	11	14	0.05	0.05	—

* All values to be multiplied by 10^6

† Modulus of rupture—modulus of elasticity.

A. 100% clay, fired to cone 12.

B. 50% clay, 50% grog (of same clay), fired to cone 15.

E.J.V.

The deterioration and failure of glassworks refractories. B. M. PEARSON. *Glass Ind.*, **8** [6], 127–33(1927).—Roughly speaking, failure of refractories is caused by the

3 principal agents, (1) high temperatures, (2) chemical action, resulting in corrosion, and (3) mechanical stress. A refractory must be designed to withstand the effect of the principal active agent but at the same time must retain those properties which will enable it to resist successfully any other influences which would result in undermining its longevity. Refractoriness of a fire clay will depend on a number of conditions. The highly refractory nature of fire clays is rather curious as, starting with alumina, which is quite highly refractory, and adding silica, a composition is arrived at which results in maximum fusibility, and which is almost the same as the composition of the majority of refractory fire clays. The resistance of a tank block to the chemical corrosion of the glass will depend upon several factors, all more or less related. Important factors are the mineralogical condition, porosity, uniformity, and fineness of texture, chemical composition of the block, and also external factors such as the composition of the glass and the working temperature of the furnace. The various factors are discussed in detail. A thorough discussion of the changes in mineralogical composition of the blocks caused by the application of heat is presented. Conditions under which corundum and sillimanite crystallize out from melts of the alumina silicates of the bases, lime, potash, and soda are listed. Chemical corrosion is undoubtedly the chief cause of tank block failure. The mechanism of corrosion is explained. Disintegration of a composite material in a solvent depends on (*a*) the density of the solute-rich layer, relative to the solvent, (*b*) the size of the particles. The effect of temperature in effecting the chemical corrosion of the block is discussed in considerable detail, the action of the various ingredients in the glass batch being taken up. Glass composition should be kept constant as a change of composition would upset the equilibrium between the glass and the refractory and a new set of conditions would have to be set up, and corrosion is very severe while this is taking place. E.J.V.

The porosity of fire brick. G. M. NAVE. *Pottery Gaz.*, **52** [600], 990–91 (1927); reprinted from *Jour. Soc. Chem. Ind.*—A comparison of various methods for determination of the apparent specific gravity of fire brick was made. The best method was found to be by coating the brick with another substance of known specific gravity to prevent penetration of liquid into the pores. The most suitable substance was paraffin wax. The weighed brick is coated with wax and the brick and wax are weighed in air and suspended in water. The calculation then is as follows: Wt. of wax $= W_x$; density of wax $= D_x$; wt. of wax in water $= W_x(D_x-1)/D_x = W_{xw}$; wt. of brick sample $= W_1$; wt. of brick + wax $= W_1+W_x$; wt. of brick + wax in water $= W_w$; wt. of brick in water $= W_w - W_{xw} = W_2$; then apparent specific gravity of brick $= W_1/(W_1-W_2)$. The real specific gravity is best determined by using the specific gravity bottle method, with xylene, for example, as the liquid. The material should be preferably ground to pass a 200-mesh sieve. The porosity is then calculated by use of the formula: porosity = (real specific gravity − apparent specific gravity) × 100 ÷ real specific gravity. E.J.V.

The position of the magnesite industry. A. W. COMBER. *Chem. Age* (London), **16,** 352–53 (1927). (*C. A.*)

Refractoriness and chemical composition of clays. W. SCHUEN. *Tonind. Ztg.*, **50,** 794 (1926).—The relation between refractoriness and chemical composition is found by the formulas: Refractoriness (1) in Seger cones $= \frac{113\ Al_2O_3 - RO}{4.48}$; (2) in °C $= \frac{360\ Al_2O_3 - RO}{0.228}$, in which the alumina and the RO are expressed in percentage weight and so calculated that $SiO_2 + Al_2O_3$ in the particular analysis equals 100. (*Trans. Ceram. Soc.* [Eng.])

Resistance of refractory materials to slags. W. KORBER. *Zpravy Ceskoslov. Keram. Spol.*, **2,** 13 (1925).—Data on the effect of slags on refractories are presented.

Figures are given relating to damage caused in practice owing to the bad quality of refractory linings in Martin furnaces, etc. (*Trans. Ceram. Soc.* [Eng.])

BOOK

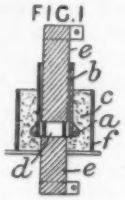
Les argiles réfractaires. CARL BISCHOF. Translated from the 4th German edition by A. Schubert. Paris: Dunod. 416 pp.; 63 francs (bound), 55 francs (paper). Reviewed in *Rev. gén. colloides*, **7**, 440 (1927). (*C. A.*)

PATENTS

Refractory lining. ROBERT B. POGUE. U. S. 1,629,047, May 17, 1927. A refractory lining comprising substantially 40% ganister, substantially 40% mica schist, and 10 to 20% of fine clay, in such proportions that expansion and contraction of the ingredients under heat is compensated.

Fused silica, quartz and silice. ANON. Brit. 266,711, April 27, 1927. A method of enlarging or building-up an article of fused silica, by the addition of more material, consists in surrounding the article with pulverized silica and in heating it locally at the place to be enlarged, so that both the article and some of the pulverized silica become plastic and are fused together. In the construction shown, a tube of fused silica is placed in a container and is packed around with pulverized silica. An electric heating element, connected with supply leads, is arranged in the interior of the tube. The part of the tube surrounding the heater, and a part of the pulverized silica become plastic and are welded together. The element may be heated by high-frequency induction, and the absence of the leads enables a bottom to be fused on to the tube. By raising the tube and keeping the element stationary, the tube can be lengthened by the progressive addition of the pulverized silica.

FIG. 1



Refractories containing silicon carbide. S. SIEURIN. Brit. 259,805, Dec. 29, 1925. From 30 to 90% of silicon carbide is mixed with a binder consisting mainly of free silica with a little clay or lime. With a clay binder, at least 80% of SiO_2 must be used; with 2% of lime present, the proportion of SiO_2 must be at least 90%. (*Trans. Ceram. Soc.* [Eng.])

Refractory substances containing magnesium. BORGESTAD FABRIKER. Brit. 260,298, Oct. 23, 1926. Artificial magnesium orthosilicate is obtained by heating a correctly proportioned mixture of calcined magnesite and talc from 1000 to 1400°. The material may also be used as a refractory cement. Excess of silicic acid must be avoided. (*Trans. Ceram. Soc.* [Eng.])

Refractories: rendering nonplastic materials plastic. SCHEIDHAUER AND GIESSING, A. G. Brit. 264,192, Jan. 11, 1926. A small proportion of the nonplastic material used for making refractories, etc., is converted into colloidal solution to act as a bond for the remaining granular material. (*Trans. Ceram. Soc.* [Eng.])

Terra Cotta

Drying problems of terra cotta. FRANK A. KIRKPATRICK. *Jour. Amer. Ceram. Soc.*, **10** [7], 469–86 (1927).—A description is given of the method of drying terra cotta and the results obtained at the plant of the Kansas City Terra Cotta and Faience Company of Kansas City, Mo., a plant having a production capacity of 200 to 400 tons of terra cotta per month. The drying processes are found to be governed by a plant problem and a ceramic problem. The experience obtained has led to the decision to abandon large steam-heated driers and build smaller units heated by natural gas.

The true functions of terra cotta. J. F. WATKINS. *Brit. Clay-Worker*, **36** [420], 20–21 (1927).—A dissertation on terra cotta covering the following subjects: (1) the bane of repetition, (2) the value of plasticity, (3) the texture of terra cotta, (4) the demand for color, and (5) broad effects essential. R.A.H.

White Wares

Hydrogen-ion concentration and electrical conductivity of clay slips 1. Plant study. A. H. FESSLER AND HOBART M. KRANER. *Jour. Amer. Ceram. Soc.*, **10** [7], 501–507 (1927).—The apparatus and method of determining the H-ion concentration and electrical conductivity of clay slips are described. Measurements were obtained on daily samples of tap water, casting and plastic slips, car shipments of clays, and individual blungers of slips in an endeavor to find whether any variations that might occur in the plant processes could be traced to variations in the slips indicated by these measurements. In a following paper values will be given showing the effect of temperature, time and vigor of stirring, specific gravity and concentration of various salts such as NaCl, Na_2SiO_3, $MgSO_4$, and $AlCl_3$ on the H-ion concentration, viscosity, and electrical conductivity of slips.

Studies of the changes in the viscosity of clay slips; and glaze suspensions on aging and by treatment with electrolytes. JAMES R. BOWMAN. *Jour. Amer. Ceram. Soc.*, **10** [7], 508–16 (1927).—The rate and extent of the spontaneous thinning out of clay slips and glaze suspensions were measured; the effects of electrolytes on the viscosities of slips and glazes after aging until minimum viscosity was reached were investigated; measurements of the rate and extent of the spontaneous thinning of a glaze after treatment with electrolytes were made; and further experiments bearing on spontaneous thinning were conducted, such as heating the slip or glaze and the application of the colorimetric method in determining p_H, etc.

III. Progress Report on investigation of sagger clays; their elasticity and transverse strength at several temperatures. R. A. HEINDL AND W. L. PENDERGAST. *Jour. Amer. Ceram. Soc.*, **10** [7], 524–34 (1927).—This is a 3rd Progress Report, based on data obtained in an extensive investigation of sagger clays for the purpose of determining the properties characterizing clays best suited to this type of service. The Report contains a brief description of the apparatus used in the determination of elasticity and transverse breaking strength at 3 temperatures, ranging up to 925°C. These data are correlated with thermal expansions of clays, as given in the 2nd Progress Report, resulting in the formation of an empirical formula which indicates the relative resistance of saggers to failure due to thermal shock. The majority of clays show an increased rigidity or elasticity at higher temperatures, but only those clays which are weak at room temperature indicate a marked increase in transverse strength.

Note on the solubility of fired bodies in hot sulphuric acid. A. V. BLEININGER. *Jour. Amer. Ceram. Soc.*, **10** [7], 535–37 (1927).—This work is an application of the so-called mineral analysis to bodies fired to a maximum temperature corresponding to cone 9, for the purpose of establishing a measure of the progressive vitrification. It is based on the assumption that the solubility of an earthenware body in hot sulphuric acid decreases with the temperature of firing, as the porosity decreases. In general, this was found to be true but in order to obtain consistent results it is necessary to maintain standardized conditions of procedure especially in the grinding of the sample and in the treatment with fuming acid. The procedure has shown solution of as much as 66% of the anhydrous clay substance with a porosity of 17.9%.

Further investigation of feldspar. ANON. Bur. Stand., *Tech. News Bull.*, No. 121, pp. 10–11 (1927).—Work has been done on the effect of feldspars on (1) relative glaze fit, (2) mechanical strength, volume shrinkage, and porosity of vitreous and semivitreous bodies, and (3) thermal expansion of vitreous and semivitreous bodies. Methods of conducting tests described, and some results are given. R.A.H.

The casting of clays and its application to art and industry. P. RENAULT. *Rev. Mat. Constr. Trav. Pub.*, **209**, Pt. I, 25–28 (1927).—The casting of clays has many advantages over preëxisting methods of shaping clay ware. Industrially, casting is

applied to the following: (1) ware which cannot be formed mechanically such as odd shapes of vases, table ware, and certain electrical porcelain, (2) articles which are sometimes made by pressing but are more easily cast, such as oval and square plates, and (3) certain pieces which ordinarily are pressed or molded but which may be cast, such as saggers, glass pots, and refractory brick. The following are the advantages of casting: (1) saving of hand labor, (2) greater efficiency, and (3) better quality of products obtained. As in industry, so also in art, casting of clays has proved of great worth enabling the production of many delicate pieces at a lowered cost. There are 2 classes of ceramic bodies which may be differentiated in the following manner: the first those which on screening leave no residue on the screen such as porcelain bodies, faiences, and in nature the greater part of the clays. The second class includes those which leave a residue of nonplastic on the screen such as sagger bodies, glass pots, etc., and in nature the siliceous clays. One example of a porcelain body of the first class is of the following composition:

Hard clay	200
English clay 1st. quality	400
Flint	150
Feldspar	150
Whiting	35
	935

An example of a stoneware body of the same class,

Stoneware clay (Clerac)	330
Kaolin	265
Feldspar	75
Flint	330
	1000

R.J.P.

Faults in alkaline slip casting. WALTER EMERY. An address before the National Council of the Pottery Industry at Stoke-on-Trent, England, Oct. 7, 1925.—A series of notes on whiteware alkaline casting slips is given. Plasticity of clay is considered the most important inherent property of clays. Removal of water, making of ware, and drying are closely connected to the plasticity of the body. A discussion of the relation of the colloidal state to the properties of clays is given. It is shown that the colloidal state of the clays is affected by various electrolytes, some tending to flocculate facilitating sedimentation, others to deflocculate retarding settlement. An excess of a deflocculating agent usually causes flocculation. The effect of sodium silicate on the viscosity of a slip is shown graphically with the maximum effect shown at 4.5% sodium silicate. Attention is drawn to the various raw materials and mill materials such as ball clays, sodium silicate, soda ash, etc., and the effect of impurities in these materials. The presence of calcium and magnesium sulphates in water has a harmful effect, when continued use of "press" water is made, due to the concentration of these salts. It is pointed out that in waste slip return the return pipe should be so located that the fall through air space is a minimum. R.J.P.

Concerning the expansion behavior of raw sagger materials containing quartz. E. KIEFFER. *Ber. deut. keram. Ges.*, **8** [2], 73–92 (1927).—A report of an investigation of the effect of alkalis on reducing the irregular expansion of sagger bodies containing quartz over the interval 150°C to 240°C. There is a considerable increase in expansion over this interval for fired bodies which contained quartz before being fired. Eight clays were used in the tests and the following series of bodies were made up and their expansions determined: (1) 65% clay to be tested and 35% blue clay containing .38% alkalis, (2) 65% clay to be tested and 35% Zettlitzer kaolin containing .06% alkalis,

(3) 65% clay to be tested, 28% Zettlitzer kaolin, and 7% Norwegian feldspar (.67% K_2O 2.7% Na_2O), (4) 65% clay to be tested, 32.5% blue clay, and 2.5% feldspar (.24% K_2O .10% Na_2O), and (5) 65% clay to be tested and 30% blue clay and 5% feldspar (.48% K_2O .20 Na_2O). These bodies were fired to cone 14. Bodies of series 3 and 5 showed less irregularity over the interval 150° to 240°C than the others. Bodies of series 2 showed considerable increase in expansion over this interval. The use of a bonding clay high in alkali tends to reduce this irregularity caused by free silica. The addition of a small amount of feldspar also reduces this irregularity but at the same time reduces slightly the softening temperature of the body. F.P.H.

Application of X-rays and fluorescent rays to white wares. O. KRAUSE. *Ber. deut. keram. Ges.*, **8** [2], 114–30 (1927).—The following problems are studied by means of X-ray photographs: (1) the changes taking place in clays during heating, (2) the changes taking place in porcelain bodies during firing, and (3) investigation of porcelain bodies. The results are reported in tables showing the values of ϕ in the Bragg equation $n\lambda = 2d \sin \phi$ and the relative intensities are denoted. F.P.H.

Using waste heat to aid production. ANON. *Ceram. Ind.*, **8** [6], 657 (1927).—A description of a few innovations to be found at the plant of the Aetna Porcelain Co. Slush coats are moved along faster by being dried rapidly with waste heat. F.P.H.

New million dollar Abington sanitary plant to grind its own raw material. ANON. *Ceram. Ind.*, **8** [6], 667–71 (1927).—A description of the new plant of the Abington Sanitary Manufacturing Co. is given. Over 20,000 pieces of sanitary ware per month are produced. Air separation of raw material and unique grouping of operating units are features of this new plant. Numerous photographs of the different units are given. F.P.H.

From the white ware industry. EDUARD BERDEL. *Tonind. Ztg.*, **50** [50th Anniv. No.], 43–46 (1926).—A short history of white ware is given. The work on glazes by Seger is cited. The changes that have taken place in the last 50 years in the manufacture of pottery, stoneware porcelain, and general whiteware are described. Seger's contribution to this field is stressed. Numerous formulas for glazes and bodies are given. F.P.H.

Faulty glazes. ANON. *Keramos*, **6** [3], 93–96 (1927).—A description of the failure of glazes is given. Seger's rule for the compounding of glazes to fit certain bodies is given. F.P.H.

The efficiency of round porcelain glost kilns. B. H. B. *Keramos*, **6** [3], 97 (1927). F.P.H.

Porcelain exhibition at Selb, 1926. ANON. *Keramos*, **5** [7], 333–40 (1926).—A description of exhibits of equipment and ceramic products at the exhibition. E.J.V.

Shenango Pottery Company to erect four new tunnel kilns. ANON. *Pottery, Glass and Brass Salesman*, **35** [16], 27 (1927).—Contracts for 4 Dressler tunnel kilns and for buildings to house them have been let. E.J.V.

"Press" porcelain. T. E. L. *Sprechsaal*, **59**, 198 (1926).—In America large pieces are made by the press method without the addition of oil; only the molds are greased with oil. Considerable savings are effected. (*Trans. Ceram. Soc.* [Eng.])

Wall and floor tiles. K. HINEIS. *Zpravy. Ceskoslov. Keram. Spol.*, **1**, 164 (1924).—The historical development of tile manufacture is reviewed. Among others, the work of Lucca della Robbia, Delft, and John Stadler of Liverpool is mentioned. Coal instead of wood was first used by Villeroy & Boch in 1809, and the same firm introduced dry pressing according to an English invention in 1846. (*Trans. Ceram. Soc.* [Eng.])

PATENTS

Ceramic process and product. THEODORE C. PROUTY AND WILLIS O. PROUTY. U. S. 1,628,910, May 17, 1927. The process of manufacturing ceramic articles which comprises the operations of subjecting the bisque to a maximum heat limited to a relatively narrow range of temperature and forming the bisque mixture of material that has a relatively narrow range of contraction within the range of temperature.

Process for the production of molybdenum trioxide and Tungsten trioxide. PAUL SCHWARZKOPF. U. S. 1,629,004, May 17, 1927. In a process for the production of molybdenum trioxide and tungsten trioxide from their ores, melting the respective ore and evaporating the oxide from the ore while in the molten state.

Porcelain. FRANK H. RIDDLE. U. S. 1,631,695, June 7, 1927. The process of forming a ceramic material containing crystals that are not subject to volumetric changes, other than those that can be explained by thermal expansion, within the range of temperature used in forming the product, which consists in forming a mixture containing at least 20% of such crystals and other material from which additional crystals having the characteristics may be formed, and firing the mixture to produce such additional crystals.

Ceramic insulating material. JOSEPH A. JEFFERY AND EARLE T. MONTGOMERY. U. S. 1,631,729, June 7, 1927. A ceramic material consisting of sillimanite crystals and a glassy matrix.

Ceramic material. JOSEPH A. JEFFERY AND EARLE T. MONTGOMERY. U. S. 1,631,730, June 7, 1927. A batch for ceramic material comprising a material amount of a heat-formed constituent containing alumina, silica and a flux, the proportion of alumina to silica in the constituent being nearer their proportion in sillimanite than is their proportion in clay.

Equipment and Apparatus

Electric trucks. G. HELM. *Ber. deut. keram. Ges.*, **8** [2], 65–72 (1927).—A description is given of a number of small electric trucks for use around a ceramic plant. H. shows that in a certain plant a saving of 34% in transportation costs resulted with the installation of small electric trucks to take the place of trucks that were pushed around by the men. The different types of trucks are illustrated. F.P.H.

Find metal racks more economical. ANON. *Ceram. Ind.*, **8** [6], 658 (1927).—At Roesch Enamel Range plant both wooden and metal racks were tried out. Considerable economy is claimed for the metal racks over the wooden type. The metal racks are made of angle iron forms. Another interesting item at this plant is the oil cut off control which automatically stops the flow of oil should the power on the blower line fail. F.P.H.

Air separation methods used in fine grinding of rock products. EDMUND SHAW. *Rock Prod.*, **30** [11], 53–55 (1927).—A description of the Raymond air separator and the Bonnot separator. F.P.H.

Saving heat with recuperator. W. A. FITCH. *Brick Clay Rec.*, **70** [11], 858 (1927).—F. states that this equipment has been little used in the clay industry but extensive use of the tunnel kiln makes a consideration of recuperators advisable. A cross-section through a recuperator of the type used by the Hanley Co. on a tunnel kiln is shown. F.P.H.

Better metals for the harder jobs. ANON. *Brick Clay Rec.*, **70** [12], 925–29 (1927). —In connection with greater use of machinery in ceramic work there arises the question of suitability of various metals for different parts of the machinery from a standpoint of service they give. The methods of production and physical properties of cast iron, malleable cast iron, wrought iron, and steel are taken up. The processes of steel making are discussed and the effect of chemical composition upon physical properties of steel

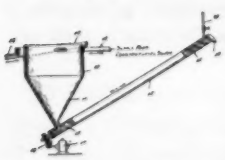
is shown. Alloys of steel with chromium, manganese, tungsten, and other materials which increase its strength, hardness, and toughness, and special uses for them in working parts of ceramic machinery are enumerated. Machines and machine parts which can be profitably made of special metals are listed. E.J.V.

What can the ceramist learn from the machine industry? U. SAUER. *Keramos*, 5 [4], 181–82 (1926).—Methods and processes in the machine industry which would be worthy of a ceramist's study are discussed. E.J.V.

Drilling holes in glass. B. BROWN. *Jour. Sci. Instruments*, **4**, 205 (1927).—Holes in glass are drilled by use of a copper tube and an abrasive, such as emery powder. While there is nothing wrong with this method, a special tool is necessary which is not always just convenient if the hole is required immediately. A drill of the ordinary type sharpened in the usual manner was used; the actual size of the hole is of small importance. It is well to choose a drill about 0.005 inch smaller than the hole required. A cutting compound consisting of a saturated solution of camphor in spirits of turpentine is used. The drill should be run slowly and a liberal supply of the compound applied. A good cutting pressure should be given to the drill, but this must not be so great as to cause flexure. It is necessary to have a good support beneath the glass which is being cut. The cutting will not be done at the same rate as for mild steel. In the laboratory the file is a most useful tool for the cutting of glass tube and rod. Any shape may be cut out if care is taken. O.P.R.O.

PATENTS

Whirlpool classifier and classifying process. RAY T. STULL. U. S. 1,629,182, May 17, 1927. The process of separating colloidal or quasi-colloidal particles from the fine granular particles, consisting in delivering a mixture of such particles suspended in liquid tangentially to the outer portion of a horizontally extended internally unobstructed body of liquid under impetus sufficient to establish a horizontal whirl having an angular velocity which decreases toward the center, overflowing a thin sheet of liquid carrying the quasi-colloidal particles from the periphery of the liquid body above but close to the level of the feed, and collecting the granular particles below the feed region.



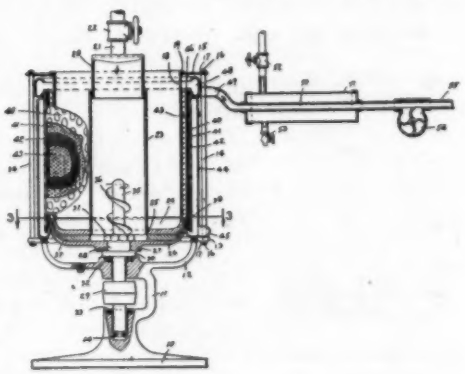
Apparatus for grading abrasive and applying same to continuous grinding systems. HALBERT K. HITCHCOCK. U. S. 1,629,502, May 24, 1927. In apparatus for surfacing glass and the like, the combination of 2 grinding systems each comprising a series of grinding machines adapted to progressively and successively surface the material being ground, separate abrasive supply systems associated with the respective grinding systems and each comprising a plurality of liquid-suspension distributing and storage vessels, separate constantly operative means with each system to supply each of the vessels with graded abrasive, and connections for supplying each grinding machine with abrasive from a distributing vessel of its own series and from a distributing vessel of the other series. In apparatus for surfacing glass and the like, by a series of continuous operations, the combination of a series of grinding runners arranged to act in succession on a sheet to be surfaced, grading apparatus comprising a primary grader and a series of secondary graders for dividing an abrasive in suspension in a liquid into various grades ranging from coarse to fine, means for conducting progressively finer grades of abrasive to successive grinding runners, whereby the successive runners produce a progressively finer and finer surface on the sheet, and means for supplying sufficient new abrasive to maintain approximately constant the various grades in the primary grader. In apparatus for surfacing glass and the like, the combination of a series of grinding runners, means for continuously moving a sheet to be surfaced to the grinding runners in succession, grading apparatus for dividing an abrasive in suspension in a liquid into various grades, a series of secondary grading vessels located at intervals adjacent the series of grinding runners, means for

separately conducting the various grades to different ones of the secondary grading vessels, means for separately withdrawing the grades from the secondary grading vessels and conducting the same to different ones of the grinding runners, means for returning the drainage from the grinding runners to the grading apparatus, means to eliminate the worn out abrasive from the system, and automatic means for supplying sufficient new abrasive to maintain approximately constant the quantity of abrasive in the primary grader.

Dust-extracting unit. ALBERT H. STEBBINS. U. S. 1,629,593, May 24, 1927. A material separating and dust extracting unit, comprising a combination, at least 3 separate receptacles connected in a closed circuit and including a suction dust extractor, a blast dust extractor and a separator positioned between the 2 dust extractors, means for delivering the materials to be treated to the separator, a fan included in the circuit at a point between the 2 dust extractors and operable to force the air repeatedly around the circuit through the different receptacles, and a by-pass conduit arranged to by-pass part of the air from one side of the closed circuit to the other without passing through the separator.

Air classifier. ALBERT H. STEBBINS. U. S. 1,629,594, May 24, 1927. An air classifier, comprising in combination, an outer casing and an inner casing having an annular air passage between them and the inner casing having a plurality of longitudinally extending slots formed through its side walls in angularly spaced relation to each other, means for introducing air into the annular passage through the wall of the outer casing at points opposite said slots, means for delivering air bearing the materials to be treated into the annular passage with a whirling movement, and suction means for drawing air from the openings in the outer wall of the casing across the passage into the slots at right angles to the path of the air traveling in the passage to thereby draw into the inner casing the lighter particles whirling in the annular passage.

Dehydrator for clay slips. JACOB P. TETER. U. S. 1,630,280, May 31, 1927. A dehydrator comprising a rotatable annular filtering wall, a second and stationary wall in spaced relation therewith forming an annular channel therebetween, means on the second wall for causing longitudinal or axial movement of the filtered solids, an annular receiver adjacent the top of the filtering wall into which the solids are discharged by the means, a pair of bowls beneath the walls and in spaced relation with each other forming a channel communicating with the first mentioned annular channel, means for supplying filtering material to the bowl channel, and means for rotating the bowls and the rotating wall for dehydrating the material.

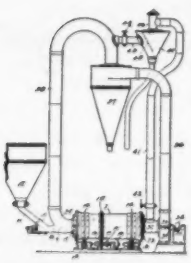


Apparatus for forming dovetail or undercut recesses in clay or other plastic material. LUCIEN GAISMAN. U. S. 1,629,660, May 24, 1927. In means for forming dovetail or undercut recesses in plastic materials, a rod with enlargement at one end, such enlargement being part of a cone, and a rubber sleeve slidably mounted on the rod, the bore of the sleeve at the part nearest the rod enlargement being of like shape to the enlargement and the wall of the sleeve at such part being flexible, and adapted to spread out on engaging the rod enlargement, the outer diameter of the sleeve being similar to that of

the larger part of the rod enlargement, means whereby the rod is held supported, further means whereby the sleeve is held supported and clear of the rod enlargement, and means whereby the sleeve-supporting means may be yieldingly moved to force the sleeve against the rod enlargement and cause it to spread outwards and on the pressure being removed cause the sleeve to move clear of the rod enlargement and to contract, the rod supporting means, and sleeve-supporting means being movable, as one, as well as one being movable relatively to the other, as set forth.

Method and means for repressing bricks. HOWARD K. KING. U. S. 1,630,436, May 31, 1927. In a brick repressing machine, the combination of a mold box and plunger elements and operating mechanism associated and operating to bring all faces of the brick into exact dimension except the middle part of one face and to permit the middle part to project above the face to the extent required by surplus material in the brick, and means for removing the middle part to approximately the plane of the surrounding margin. In a brick repressing machine, the combination of a plurality of mold boxes, a plurality of pairs of coöperating oppositely acting plungers, one of each pair of plungers being composite, comprising a panel element, and a surrounding frame element, means for operating the frame elements and opposite plungers with definite strokes, means for operating the panel elements comprising communicating fluid containing cylinders, pistons operating therein, means connecting the pistons to the panel elements, a common fluid containing cylinder adapted to communicate with the first-mentioned cylinders, a piston operating therein, a spring supporting element connected to the piston, a plurality of springs having their lower ends engaging the element, a top plate engaging the upper ends of the springs and connected to the means actuating the frame elements, means forming a passage having a check valve for permitting flow from the first mentioned cylinders to the common cylinder, means forming a second passage between the first mentioned cylinders to the common cylinder, a valve for controlling the passage, means operated by moving parts of the machine for controlling the valve and means for limiting the downward movement of the panel elements.

Air-swept ball mill. HARRY H. WATERMAN. U. S. 1,630,992, May 31, 1927. In an air swept mill of the ball type having a substantially unobstructed interior, a fan blower having its intake connected to one end of the mill, a dust collector connected to the exhaust of the fan blower, means for supplying material at one end of the mill, and an air supply pipe leading from the collector to the other end of the mill, whereby the material is conveyed to the intake of the fan by the velocity of the spent air supplied from the collector.



Brick-making machine. ROY P. M. DAVIS. U. S. 1,631,251, June 7, 1927. A brick-making machine comprising an anvil plate having a mold supporting surface and a pallet supporting surface at different levels, with mold and pallet thereon, a liner plate between the mold and the mold supporting surface and extending over and above the pallet, means for moving the mold after the filling operation across the liner plate to a position thereon above the pallet, and means for withdrawing the liner plate from between the mold and the pallet.

Kilns, Furnaces, Fuels, and Combustion

Notes on firing in downdraft periodic kilns. ROBERT LINTON. *Jour. Amer. Ceram. Soc.*, **10** [7], 493–500 (1927).—The results of a series of investigations chiefly in connection with firing are presented, with a general discussion of factors entering into the heat treatment of silicate materials. These include (1) factors controlling firing,

(*a*) specific heat of the clay body, (*b*) heat of dissociation of the hydroxides, (*c*) latent heat of fusion, and (*d*) heat of reactions which take place under fusion; (2) fuel consumption and temperature rise; (3) heat distribution in the kilns; (4) firing economies; (5) cooling; and (6) dehydration and shrinkage.

Notes on recent developments in fuel technology. R. WIGGINTON. *Fuel in Science and Practice*, **6** [5], 193–96 (1927).—A review of the work being done in fuel technology by members of various technical organizations especially in England. Among the progress mentioned is the possibility of separating slate from coal mechanically by color difference. Mention is also made of a paper by C. Benedicks and H. Lofquist, "Theory of Cast Iron Repeatedly Heated." There is also noted the increase in briquetting of coal in America from 66,524 tons in 1907 to 995,332 tons in 1926. Several important developments in low-temperature carbonization of coal are discussed. The increase in the use of water-gas is reviewed. There is mentioned the possibility of the formation of an American Fuel Research Board with members from leading technical societies together with the Bureau of Mines and Bureau of Standards. A discussion is given of the paper "Fusibility of Coal Ash as Related to Clinker Formation" which is Bulletin 29 of the Carnegie Institute of Technology collaborating with the U. S. Bureau of Mines. R.J.P.

Waste heat as air for combustion in downdraft kilns. W. A. BUTLER. *Clay-Worker*, **87** [6], 468–69 (1927).—A description of the recuperative and regenerative systems is given. F.P.H.

The combustion chamber of steam boilers burning powdered coal. WINTERMEYER. *Feuerungstechnik*, **15** [15], 169–72 (1927).—The refractory must be able to withstand high temperatures and considerable temperature variations and possess a great deal of resistance to the action of slags. The types of combustion chambers in use are illustrated. F.P.H.

Contribution to the calculation of the combustion of powdered coal. WILHELM GUMZ. *Feuerungstechnik*, **15** [15], 172–74 (1927). F.P.H.

On the introduction of briquette firing in the ceramic industry. ANON. *Keramos*, **5** [8], 367–68 (1926).—A discussion of the various types of fuels available. Advantages of use of briquettes as a fuel for ceramic purposes are enumerated. E.J.V.

Carbon ratios of coal as index of oil and gas. G. S. HUME. *Can. Min. and Met. Bull.*, No. 179, pp. 32–45 (1927).—The "carbon ratio" is the recalculated per cent of fixed carbon after ash and moisture have been eliminated. Carbon ratios as applied to the mid-continental and Appalachian fields of the U. S. are not wholly applicable to the Albertan field, a heavier grade of oil being found in Canada for the same ratio. The following table is used as the standard of comparison: Carbon ratios over 70, no oil or gas; 70–65, no commercial production; 65–60, gas wells common, oil pools rare but exceptionally good; 60–55, the principal fields of light oil and gas; 55–50, the principal fields of Ohio, Indiana and mid-U. S.; under 50, heavy coastal-plain oil. H.H.S.

BOOKS

The Fundamentals of Heat Conductivity. FRIEDRICH MERKEL. Published by Th. Steinkopf. Dresden, 1927. Reviewed in *Keramos*, **6** [3], 120 (1927). F.P.H.

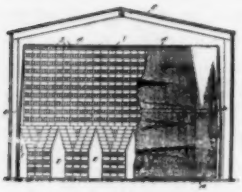
Introduction to the chemical technology of fuels. E. GRAFE. Published by Th. Steinkopf. Dresden. Reviewed in *Feuerfest*, **3** [4], 66 (1927). F.P.H.

PATENTS

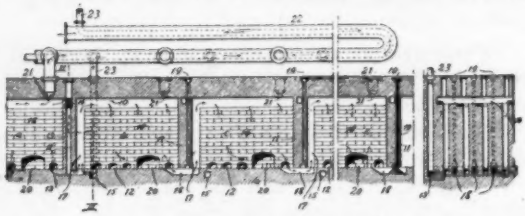
Rotary kiln. A. LACORE AND J. PIRON. Brit. 259,238; *Rock Prod.*, **30** [11], 90–91 (1927).—A rotary kiln for burning lime or cement is provided with 2 enlarged zones, each about double the regular diameter of the kiln, situated between 3 regular kiln sections. The regular section at the lower end of the kiln constitutes the clinkering zone

and is followed by an enlarged section (calcining zone). The enlarged section at the raised end of the kiln is the preheating zone. F.P.H.

Method and means for baking brick. JAMES MCLAUGHLIN. U. S. 1,631,144, June 1, 1927. A scoving for baking brick comprising a plurality of loosely associated sheets of heat-retaining material placed over a stack of bricks to be baked and resting thereon.



Apparatus and process for firing ceramics and the like. HEINRICH KOPPERS. U. S. 1,631,536, June 7, 1927. An annular oven for firing ceramic ware and the like, in combination: a series of connected oven chambers adapted to be operated successively as cooling, firing, and preheating chambers; partitions separating the chambers; a plurality of passage openings in the partitions, one set in the upper portion of the partitions providing a communication from the upper part of one chamber to the lower part of the next adjacent chamber and the other set of passage openings located in the lower portion of the partitions and communicating with the lower part of the next adjacent chamber, each of the passage openings adapted to be opened and closed; openings in the lower portions of the chambers for admission of cooling air; heat supply openings located in the lower part of the chambers adjacent the partitions; the passages in the upper part of the partition adapted to be opened and the passages in the lower part of the partitions adapted to be closed between the cooling and firing chambers; the upper passages adapted to be closed and the lower passages adapted to be opened between the firing and preheating chambers and between each preheating chamber.



Geology

Pre-Cambrian rocks in Northern Quebec. J. H. C. MARTENS. *Can. Min. and Met. Bull.*, No. 177, pp. 98–126 (1927).—An account of Cornell field work along the Ashnapmuchuan river, 180 miles northwest of Quebec. The rocks are highly metamorphosed sediments with minerals, sillimanite, feldspar, biotite, and garnet, characteristic of the high-pressure zone of metamorphism. H.H.S.

Antimony and its compounds. W. V. SMITHERINGALE. *Can. Min. and Met. Bull.* No. 180, pp. 414–68 (1927).—A comprehensive account of the world's deposits of Sb, their objectionable impurities and buyers' penalty specifications, with notes on the properties and uses of Sb and its compounds. In production, China is easily first, Algeria second, and Mexico third. The world's capacity for producing Sb far exceeds the normal demands. H.H.S.

Barites. ANON. *Mining Rev.*, No. 44, South Australia Dept. of Mines, p. 53 (1926).—A regular output of first and second grade barites is maintained from the mine near Noarlunga. There is no treatment plant on the mine; the crude ore is bagged and sold as such, second grade being accepted where purity of color is not essential. O.P.R.O.

Corundum. C. J. N. JOURDAN. *Jour. Chem. Met. Min. Soc. of South Africa*, **26**, 331 (1926).—Corundum is found in unlimited supplies in the "reefs" below some of the

crystal occurrences. This mineral can be extracted from these reefs in form of grain corundum by ordinary processes of milling and concentration. In this form the Union of South Africa is in a position to supply industry for an indefinite period. O.P.R.O.

Kaolin. C. J. N. JOURDAN. *Jour. Chem. Met. and Mining Soc. of South Africa.* **26,** 328–35 (1926).—There are important occurrences of kaolin in South Africa, sufficient for domestic requirements, if and when the pottery and allied industries are inaugurated. O.P.R.O.

Valuation of fluorspar. ANON. *Glass Industry,* **8** [6], 138–39 (1927).—The occurrences of fluorspar, calcium fluoride, in various localities are discussed. A method for the complete quantitative analysis of fluorspar is given, with notes on the types of apparatus, reagents, and procedures. The determination of iron in the fluorspar is also outlined. E.J.V.

Chemistry and Physics

Relation of composition and heat treatment to industrial properties of ceramic products. EDITORIAL. *Bull. Amer. Ceram. Soc.,* **6** [6], 163–70 (1927).—Ceramics is defined. The production of ceramic ware to suit specifications is discussed. Ceramic ware is made with raw materials and the properties of the ware are dependent on fused and unfused portions and are related to the mineral constitution. Ceramic science is exact in fundamentals but empirical in application. The composition of clays and factors determining the suitability of clays for specific ware are discussed. The fact that heat history has a marked effect on ware property is shown by comparing the beneficial effect of long heat treatment to clay ware and its damaging effect to glass. Devitrification, crystallization, and solid solutions are taken up. The importance of equilibrium studies of fusions is shown. A plea for fundamental ceramic research is made. E.J.V.

Misemployment of fundamental science concepts. EDITORIAL. *Bull. Amer. Ceram. Soc.,* **6** [6], 170–71 (1927).—The failure of attempts to correct faults in various types of ware by application of fundamental data which holds true for one particular type is discussed. Tests so far have not measured fundamental causes but rather composite effects. Empirical researches will always be necessary in making application of fundamental facts relating to ceramic materials, but more fundamental facts must be known regarding silicate fusions. The need for a National Ceramic Research Council is stressed. E.J.V.

On the quantitative determination of sulphates in the form of barium sulphate. V. MARJANOVIC. *Arhiv za Hemiju i Farmaciju,* **1** [1], 5–18 (1927). E.J.V.

Practical experience with rational analysis of kaolins. GUSTAV KOPKA AND FRIEDRICH ZAPP. *Keramos,* **5** [4], 183–87 (1926).—Literature on rational analysis is reviewed. The various methods are described. A comparison of the methods of Berdel and Kallauner was made and showed very little variation on the results obtained, but the Kallauner method is preferred for process control. E.J.V.

Reply to "Practical experience with rational analysis of kaolins." F. STEINBRECHER. *Keramos,* **5** [6], 286–87 (1926).—A discussion of the paper of the above title by Kopka and Zapp. E.J.V.

Thirty-third annual report of the committee on atomic weights. Determinations published during 1926. GREGORY P. BAXTER. *Jour. Amer. Chem. Soc.,* **49** [3], 583–90 (1927).—A short résumé of work published during the past year which establishes new values for various constants or reaffirms those previously published. The value of the density of boric acid glass has been obtained. The density of nitrogen and oxygen at 0°C and various pressures were determined. Considerable work was done on the atomic weight of lead in which values as low as 206.02 were found for uranium lead. A

new table of atomic weights of the elements is given by B. in which he considers it to represent the present situation. Changes from the International Table for 1925 involve the following elements: hafnium, helium, holmium, lead, titanium yttrium, and zirconium. R.J.P.

Plasticity. ANON. *Brit. Clay-Worker*, **35** [418], 310(1927).—The cause of the plasticity of clay is not determined, but partly depends on smallness of particles, a sufficient number of which must be less than 0.000,000,000,008 inch in diameter. H. Salmang has also found that the part played by water and certain other fluids in making clay plastic, is due to the presence of the hydroxyl group in the absence of which the mixture of clay and liquid does not become plastic. Salmang also suggests that plasticity is favored by the flaky shape of the clay particles, by their relative softness, porous surface and ready cleavage and possibly by other colloidal substances which may be present. For a statement of Salmang's views see *Ceram. Abs.*, **6** [7], 286(1927).. R.A.H.

Relationships between the Rockwell and Brinell numbers. S. N. PETRENKO. Bur. Stand., *Tech. Paper*, No. 334.—Comparative Rockwell and Brinell tests were made on a great variety of ferrous and nonferrous metals. The theoretical relationships between the Brinell and the Rockwell numbers may be expressed by the equations

$$\text{Brinell number} = \frac{\text{Constant}}{\text{130–Rockwell ball number}}$$

and

$$\text{Brinell number} = \frac{\text{Constant}}{\text{100–Rockwell cone number}}$$

The experimental values of Brinell and Rockwell numbers were inserted into these equations and the constants determined. These theoretical equations with the experimentally determined constants may be used to estimate, within an error of $\pm 10\%$, the Brinell numbers from the Rockwell number. Similar equations were obtained for the tensile strengths of steels which may, within an error of $\pm 15\%$, be estimated from the Rockwell number. R.A.H.

Vanadium and tungsten separation. S. G. CLARKE. *Chem. and Ind.*, **46,** 444(1927). —V may be determined in presence of large amount of W by precipitation with cupferron after treatment of the solution with HF, neutralization with NH_4OH, addition of HCl, and dilution. H.H.S.

Tungsten separation from tantalum, columbium, and their mineral associates. W. R. SCHOELLER AND C. JAHN. *Chem. and Ind.*, **46,** 444(1927).—Tungstic acid can be quantitatively precipitated by tannin and cinchonine hydrochloride. Ta and Cb remain in solution. H.H.S.

Moisture determination by the volatile solvent method. J. M. JONES AND T. MCLACHLAN. *Chem. and Ind.*, **46,** 445(1927).—For powders which cake, the use of a volatile solvent is better than the airbath. Toluene is preferred to benzine or petroleum spirit. H.H.S.

Lead determination. B. S. EVANS. *Chem. and Ind.*, **46,** 445(1927).—Pb is separated from HNO_3 solution as sulphate. Bi is determined colorimetrically with KI, As is precipitated with NaH_2PO_2 and separated by shaking with benzene and then determined with I; Sb is determined in the filtrate. S is estimated on a separate sample by evaporation to dryness. H.H.S.

Manganese and ferro-manganese. ROBERT HADFIELD. *Engineering*, **123,** 576–78, 606–608(1927).—Gives a world-map showing all present known sources of supply of Mn ore and classifying them by output as (1) over 100,000 tons per annum, (2) under 100,000 and over 10,000 (3) under 10,000 and (4) large deposits not fully developed.

India is first with 29% of the output and Russia second with 21%, the Gold Coast and Brazil ranking 3rd and 4th. What is known on the market as "Oriental ore" is a blend of the composition Mn 51.00, P 0.105, SiO_2 7.50, Fe 6.50%. The alloys of Fe and Mn are then discussed. H.H.S.

Silicon of high purity. N. P. TUCKER. *Engineering*, **123**, 586–652 (1927).—The melting point of high-purity Si is 1415° C ± 1°. The sample was 99.945% pure, the impurities being Al and Fe. H.H.S.

BOOKS

Essays on the art and principles of chemistry. H. E. ARMSTRONG. London: E. Benn, Ltd., 1927. Price 12 *s.* 6 *d.* A characteristic book from the eminent chemist who has never accepted chemical theories on mere authority. H.H.S.

Spectroscopy. E. C. C. BALY. 3rd Ed. 4 vols. Vol II. London: Longmans, Green & Co., 1927. Price 18 *s.* H.H.S.

Treatise on Thermodynamics. MAX PLANCK. 3rd English edition, translated from the seventh German edition by A. OGG. Pp. xiv+297. London: Longmans, Green & Co., Ltd., 1927. Price 15 *s.* net. Reviewed in *Chem. and Ind.*, **46**, 408 (1927).

Thermodynamics and Chemistry. F. H. MACDOUGALL. Second edition. Pp. vii+414. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1926. Price 27 *s.* 6 *d.* net. Reviewed in *Chem. and Ind.*, **46**, 408 (1927).

General

Research and test methods for ceramic raw materials and products. ANON. *Ber. deut. keram Ges.*, **8** [2], 92–114 (1927).—Report of the Materials Testing Committee of the German Ceramic Society on standard test methods. The following test methods are described and literature pertaining to these tests is cited: (1) grain size (*a*) sieve analysis (*b*) elutriation, (*c*) sedimentation, (2) water of plasticity, (3) casting properties, (4) dry strength, (5) specific gravity, (6) water absorption, (7) apparent and true porosity, (8) absorption under pressure, (9) permeability, (10) color of fired body, (11) drying and firing shrinkage, (12) volume stability, (13) sintering, (14) softening, (15) refractoriness. F.P.H.

Three methods of cost accounting. E. J. BURTON. *Ceram. Ind.*, **8** [6], 672–73 (1927).—Dinnerware and hotel ware potteries have developed 3 types of cost system: (1) one system uses glost kiln space as unit, (2) another figures on list value, and (3) another system checks each item manufactured. These systems of cost accounting are described. F.P.H.

Glass, enamel, and pottery research data. ANON. *Ceram. Ind.*, **8** [6], 688–90 (1927).—An abstract of the report of the meeting of the Advisory Committee on Ceramics of the Bureau of Standards is given. The work of the Bureau of Standards during the last year on the following subjects is reported: (1) feldspars, (2) glass, (3) sagger clays, (4) enamels, (5) enamel slips, (6) comparison of English and American china clays, (7) effect of the chemical composition on the (*a*) modulus of elasticity, (*b*) tensile strength, and (*c*) coefficient of expansion of glazes. F.P.H.

New process for recovery of valuable mica wastes. ANON. *Ceram. Ind.*, **8** [6], 698 (1927).—The recovery of highly valuable mica wastes, hitherto lost in the ground mica industry due to incomplete settling of fine materials in the wet grinding process is described in U. S. Bureau of Mines, Report of Investigation, Serial No. 2798 entitled, "The Use of Flocculating Reagents for the Recovery of Fine Mica." F.P.H.

Rock products industry in South Dakota. F. C. LINCOLN. *Rock Prod.*, **30** [11], 34–38 (1927).—Part II of a paper on this subject. The industries covered in this article are: (1) limestone, (2) lime, (3) lithia, (4) mica, (5) ocher, (6) Portland cement. F.P.H.

Blast furnace slag as a road material. P. J. FREEMAN. *Rock Prod.*, **30** [11], 46–47 (1927). F.P H.

The history of the gypsum industry. E. MUNDT AND H. VOLKER. *Tonind. Ztg.*, **50** [50th Anniv. No.] 64–65 (1926). F.P.H.

Forty-ninth annual meeting of the Illinois Clay Workers' Association. ANON. *Clay-Worker*, **87** [6], 478–79 (1927). F.P.H.

The evolution of brick and brickmaking in the United States. GEORGE M. FISKE. *Clay-Worker*, **86** [6], 478–82 (1926); **87** [1], 53–61 (1927); [3], 231–32 (1927); [5], 378–79 (1927); [6], 476–77 (1927); [7], 542–43 (1927).—Several of a series of articles on this subject. These deal with the various associations such as the National Brick Manufacturers Assn., AMERICAN CERAMIC SOCIETY, Common Brick Manufacturers Assn., National Paving Brick Assn., Building Brick Assn., and Clay Products Assn. E.J.V.

Bonus system keeps men on the job. ANON. *Brick Clay Rec.*, **70** [12], 930 (1927).—The Richland Shale Products Co. of Columbia, S. Car., uses the task system, whereby each man is given a definite task to do each day and upon completion of which he is free to go home, and a bonus system, for being at work every working day of the week, to cement employer and employee relations. This has resulted in having more efficient and satisfied workmen. E.J.V.

Giving the employee a hand. ANON. *Brick Clay Rec.*, **70** [12], 932–34 (1927).—The Kentucky Fire Brick Co. of Haldeman, Ky., shows great interest in the general welfare of its employes, looking after recreational needs, encouraging home building, maintaining flower gardens, etc. E.J.V.

Costs and accounting as applied to the clay industry. R. C. TURNER. *Clay-Worker*, **87** [7], 554–55 (1927).—The 5th of a series of articles on this subject. The distribution of indirect costs in the clay industry, including indirect manufacturing expense, power, cost of selling, and cost of administration, is discussed. See *Ceram. Abs.*, **6** [5], 199, [6], 250 (1927); for analysis of profit and loss of clay products see *Clay-Worker*, **87**, [6], 462–63 (1927). E.J.V.

The production of artificial mother-of-pearl materials. P. M. *Diamant*, **48** [16], 308–10 (1926).—The production of imitation mother-of-pearl by coating a base with thin layers of such materials as collodion, celluloid, etc., and covering them with other layers of materials such as amyl acetate and alkali silicates, having different indices of refraction of light, are discussed. Beautiful effects are obtained by the introduction of finely divided metals into some of the layers. E.J.V.

Frederick Carder and his work. ANON. *Glass Ind.*, **8** [6], 130–31 (1927).—A brief biographical sketch of Mr. Carder, art director of the Steuben Division of Corning Glass Works, illustrated with photographs of glassware designed and executed by him. E.J.V.

Glass Container Association decides to raise big publicity fund. ANON. *Glass Ind.*, **8** [6], 142–44 (1927).—A report of the Glass Container Association's convention at Atlantic City, May 5 and 6, 1927. See also *Ceram. Abs.*, **6** [7], 312 (1927). E.J.V.

British Society holds election and meeting. ANON. *Nat. Glass Budget*, **43** [4], 16 (1927); *Pottery Gaz.*, **52** [600], 969–76 (1927).—Walter Butterworth, Sr., was re-elected president at the April meeting of the Society of Glass Technology. W. E. S. Turner read a paper on "A Brief Review of Furnace Developments." E.J.V.

The Ceramic Society's tour in Czechoslovakia and Austria. I. ANON. *Pottery Gaz.*, **52** [600], 949–57 (1927).—A description of the tour through Czechoslovakia by 68 members of the English Ceramic Society. The State Porcelain School at Fischern is described as to equipment and courses of instruction offered. E.J.V.

Experiments being made which may cut cost of firing pottery kilns. ANON. *Pottery, Glass and Brass Salesman*, **35** [17], 27 (1927).—Combustion engineers of the Manu-

facturers Light & Heat Co. of Pittsburgh are coöperating with ceramic plant owners in experiments to reduce firing costs by use of natural gas as fuel. New type burners and methods of firing kilns so as to get the most heat out of the gas are being studied. E.J.V.

German ceramic science progresses. ANON. *Keramos*, **5** [4], 177–80(1926).—A discussion of the Silicate Investigation Institute of the Kaiser Wilhelm Society for the Furtherance of Science, similar in nature to the American Refractories Institute at Mellon Institute. E.J.V.

Leader among ceramists: Carl Schumann. ANON. *Keramos*, **5** [5], 219–20(1926).—An obituary of Carl Schumann, a leader in the German ceramic field. E.J.V.

Ceramic gossip of an old porcelain maker. HEINECKE. *Keramos*, **5** [5], 223–24(1926); **5** [6], 283–86(1926).—A general discussion of information gleaned through long experience in ceramics. E.J.V.

The Kaiser Wilhelm Institute for Silicate Investigation and its aims for the present and future. WILHELM EITEL. *Keramos*, **5** [5], 225–27(1926).—The immediate aims of this Institute are outlined and some ideas as to the future investigations are advanced. E.J.V.

The chemistry of silicon. ANON. *Keramos*, **5** [5], 227–31(1926).—Abstracts of the following papers are given: "The Equilibria in Systems of Silica, Alumina, Lime, and Soda," by W. Eitel; "New Structure Determinations of Silicates," by Paul Rosbaud; "On the Physical Properties of Ceramic Bodies," by Felix Singer; "Physico-chemical Problems of Glass Technology and Ceramics," by Gustav Keppeler; "Silicon Dioxide and Its Hydrates," by Robert Schwarz; and "On the Constitution of Cement," by Ernst Jänecke. These papers were presented at the convention of the German Bunsen Society for Applied Physical Chemistry. E.J.V.

A view of the ceramic industry in the United States. A. ZOELLNER. *Keramos*, **5** [6], 271–74(1926).—A general discussion of the organization of the ceramic industry in the United States as seen on a visit to America. The distribution of manufacturers of different types of wares, details of the divisional make-up of the AMERICAN CERAMIC SOCIETY, and the ceramic course at Ohio State University are topics discussed. E.J.V.

Ceramic papers from the 39th convention of the Society of German Chemists. ANON. *Keramos*, **5** [6], 277–80(1926).—Abstracts of the following papers are given: "On Chemical Reactions in Mixtures of Solid Materials," by G. Tammann; "The Reactions in Kaolinite During the Burning Process," by K. Spangenberg; "On a Separately Wound, Rapidly Exchangeable, Electric Resistance Crucible Furnace," by A. Simon; "On a Stable Ceramic Body for Boiling," by F. Singer; "Ceramic Filtering Apparatus for Laboratory Use," by B. Weber. E.J.V.

The ceramic division of the Württemburg State Technical School in Stuttgart. HANS VON HEIDER. *Keramos*, **5** [6], 281–83(1926).—A description of the equipment, courses, and type of work done in the ceramic department of the school. E.J.V.

Leaders among ceramists: Reinhold Rieke. ANON. *Keramos*, **5** [7], 321–24(1926).—A biographical sketch of Dr. Rieke, with a list of 76 of his contributions to ceramic literature. E.J.V.

Modern instruction in chemistry and ceramics. EDUARD BERDEL. *Keramos*, **5** [7], 325–28(1926).—A discussion of modern teaching methods by the director of the State Ceramic Trade School in Bunzlau. E.J.V.

Leaders among ceramists: Alfred Bruno Schwarz. ANON. *Keramos*, **5** [8], 365–66(1926).—A biographical sketch of A. B. Schwarz, with references to some of his outstanding work in ceramic research. E.J.V.

Clays. M. L. MOYER. *Contract Rec. Eng. Rev.*, **41**, 355(1927).—The Province has exceptionally excellent clay resources from which can be manufactured all classes of

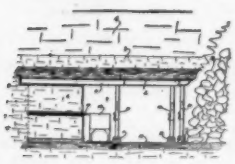
ceramic products. For a wide range of variety, freedom from impurities and for accessibility, the clay deposits of Saskatchewan, ranging from common brick clays to high grade refractories and pure ball clays, place this Province foremost in Canada in the matter of clay resources. There are 4 distinct kinds of clay distributed over southern Saskatchewan, (1) buff-firing clay suitable for manufacture of common and hollow brick, building tile, etc., (2) in the same locality is found blue clay which burns a beautiful red, (3) there are deposits of white ball clays suitable for floor and wall tile, sanitary ware, electrical porcelain, and white tableware; in tests carried out at the Univ. of Sask. this clay has proved to be equal to standard white ball clays, (4) deposits of high grade fire clay, are found and also extensive deposits of stoneware clay of excellent quality. Coal seams found under the seams of clay make conditions ideal in certain localities for extensive clay manufacturing at moderate cost. O.P.R.O.

The Institute of Fuel. ANON. *Chem. and Ind.*, **46**, 424–25 (1927).—At a joint meeting in London of the Inst. of Fuel Technology and the Inst. of Fuel Economy Engineers on April 29, it was decided to merge the two societies into the Institute of Fuel. Alfred Mond is the first President, and H. L. Pirie and E. C. Evans joint secretaries. H.H.S.

An international prize competition. ANON. *Chem. and Ind.*, **46**, 493 (1927).—The Sicilian Foundation offers 3 money prizes of 5000, 3000, and 2000 lire respectively for theses to promote progress of chemical industry in Sicily. The competition is open to all the world. Theses must be sent in duplicate by registered post before the first day of February, 1929, to "Fondazione per l'Incremento Culturale ed Economico della Sicilia," presso la Direzione Generale del Banco di Sicilia, Palermo. H.H.S.

PATENT

Method of and means for supporting roof strata during the mining of minerals. WILLIAM P. TABER. U. S. 1,630,589, May 31, 1927.



The herein described method of supporting roof strata during the mining of minerals, which consists in excavating at the top of a mineral vein, a hole which extends beyond the vertical plane of the section of minerals next to be removed, then inserting in the hole a support to rest at its inner end upon the solid minerals beyond the section thereof to be taken out, and then sustaining the support at its outer end in the space from which the minerals have previously been removed.

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Edited by the Secretary of the Society Assisted by Officers of the Industrial Divisions

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Vol. 6 August, 1927 No. 8

EDITORIALS

BRINGING RESEARCH UP-TO-DATE[1]

BY R. D. COOKE

Most of us are research workers either primarily or secondarily. At least we are here to think together along research lines and to discuss the results of research. So I may assume that we are of one mind concerning the value of research and its possibilities. We think of it as a tool of industry, a very modern tool which has not yet been used to the fullest possible extent. We are sometimes even a little concerned because those who are managing the industries fail to embrace such an obviously useful tool, and we frequently criticize them for that.

Now let us look at the picture from another angle. We, the research workers, are the managers of research activities, and a new tool in the form of a new or improved method presents itself. Do we welcome it with open minds? Sometimes, but not often. Do we scrutinize it and try to understand it? I am afraid we are generally too busy. Anyway the old ways are good enough. We are not so different from the managers of industry we criticize. This shows, merely, that human nature is very much the same wherever it is found, and one could digress to preach a little sermon on the fact that however good a thing may be it is not accepted until someone sells it.

[1] Presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, Detroit, Mich., February, 1927. (Enameling Division.)

I am going to try to be salesman for a group of new tools that have had very scant recognition in our circle. Within the past ten or fifteen years, possibly since the student days of most of us, there have come into being a number of scientific methods which offer wide opportunities for improving enameling technology, but instead of accepting them and getting what we can from them we go on with our old system of "try this and try that and see how it works."

Microscope One of these tools, which is a tool literally as well as figuratively, is the microscope. We usually think of the microscope as a magnifier. It is that of course, but of late years it has gained recognition as an instrument for quantitative measurements. Wright of the Geophysical Laboratory has found that a good idea of the composition of a feldspar can be gained in a few minutes with the polarizing microscope. He was also able to determine roughly the composition of ten soap powders in two hours, a result which would require as many days using classical chemical methods. The problem of the composition of Portland cement was solved by these methods.

Aside from being a time saver in analytical work the microscope yields information which cannot be had in any other way. Most important of these methods is the determination of indices of refraction of powdered materials. I am not going to go into detail as to what index of refraction might mean in enameling, but when we learn that the composition of stones in glass, the changes that take place in refractories during manufacture and use, and the structure of porcelain have been solved by consideration of indices of refraction, we have a feeling that we are not far from home on this ground. It is certainly a pity that quantitative microscopy has not found its place in enameling research.

Hydrogen Ion Another tool that we have not adopted is the conception of hydrogen-ion concentration, now so firmly intrenched in many industries and branches of science. I recall that a few years ago in one of the AMERICAN CERAMIC SOCIETY meetings, some upstart speaker mentioned hydrogen-ion concentration in the course of his address. His remark nearly broke up the meeting and he was reprimanded for speaking of something we did not know anything about. We may have improved since that day, but are not so open-minded yet but that there would be a remonstrance if someone were to speak of sub-atomic structure and electron activity. At any rate the bacteriologists "live and move and have their being" in an atmosphere of p_H, while fifteen years ago no one had ever heard of it. I believe it will become a part of our every day vocabulary in a few years.

Again I am not going to try to point out just how H-ion concentration applies to enamels for I do not know. What I am pleading for is an intelligent consideration of these things and a willingness to inquire

whether there are possibilities in them. I feel that there are possibilities because such important applications have been found in other lines. I have mentioned bacteriology. In electroplating it has been found that p_H is important in controlling gassy deposits. Maintaining the p_H within certain limits aids in production of desirable qualities in nickel deposits. Commercial filtration of certain materials is greatly aided by p_H control. In the clarification of water the p_H of the final mix determines the percentage of coagulant thrown out and the time required and the efficiency of turbidity removal. It also finds application in tanning, glucose manufacture, canning foods, and in many biological studies.

Colloid Chemistry The subject of colloid chemistry is so bound up with hydrogen-ion concentration that I must speak of it next. The science of colloid chemistry may be said to have begun in 1912. Many facts were determined during the preceding fifty years but it is true as Jerome Alexander has said,

> Without an understanding of the underlying principles, isolated facts have long lain like individual gems scattered or even lost in the wide fields of human experience. A theory is necessary to string them together to form a beautiful necklace.

The theory came in 1912, and since that time colloid chemistry has almost passed in stature its distinguished foster-father, physical chemistry.

We are inclined to feel that the only point of contact between colloids and enamels is the clay. I think this is a mistake. Colloid science is really the science of materials very small in one, two, or three dimensions; the science of particles, films, and filaments. The smallness of the dimensions gives to matter in this state a surface inordinately large in proportion to its mass. There are then seen surface effects outweighing the ordinary chemical effects, so that colloid chemistry may be thought of in one sense as the chemistry of surfaces.

The frit, opacifier, and colors have surfaces as well as the clay, each with its own electrical charge, iso-electric point and adsorptive properties. Do we want them to repel or attract each other, adsorb from or give up to the surrounding liquid or gas. Colloid science is the proper tool to dissect these questions. The adsorption of gaseous and other impurities in steel are colloid problems. The plastic properties of the wet ground enamel is a colloid problem involving more than clay. The furnace reactions, oxidation of the metal, gloss of the enamel, formation of the bubbles, are colloid problems. They confront us in the melting process as well. The suspension of auxiliary opacifiers, as fluorine compounds, in the glass is a colloidal phenomenon about which there is almost no knowledge.

In what industries have colloidal studies made notable improvement in technique? The manufacture of nitrocellulose, paints, leather, rubber, ore flotation, and sewage disposal to mention a few important ones. Because these are not enamel does not argue that enamel technique is not susceptible to improvement of the same character.

I am not trying to tabulate a complete list of methods which should improve our knowledge of enamels, or dogmatize on the manner of using them. I ask merely, if in dealing with a problem the question of using X-ray spectra, higher mathematics, catalytic action, or any of those I have mentioned comes up, that we be not afraid of them.

Physics There are some other tools for the research worker of a somewhat different kind from those I have been discussing. I refer to methods long and well known in sciences other than chemistry and in industries other than ceramics, and which because of the intense specialization of our time we have never encountered. I do not know of anyone trained as a physicist who is giving attention to enamel problems. How did we ever get the idea that it is primarily a chemist's job anyway? I have an uneasy feeling that if a group of physicists got to work on enamel problems the chemists would soon be in the background. It is up to the enamel research workers to burn some midnight oil and absorb a lot of information from the science of physics, particularly the parts about mechanics, light, and heat.

Methods used in other industries present a problem of a different kind. I have not the least doubt that if we only knew it there is information of many kinds, common everyday knowledge in other industries, which would be applicable to our problems. But how we are to find them out I do not know. We cannot get them by study. The only suggestion I can make is to urge the fullest intercourse with people in other lines of work. Never miss an opportunity to visit a hat factory or a tooth pick factory or a bakery. Talk shop all you can with your neighbor or your brother Elk who is in the candy business or the paint business; they all have ideas for you.

If you have seen between the lines in what I have been saying you have observed that what I am really urging is the use of less empiricism and more fundamental science in enameling research. That means of course getting more fundamental knowledge about the inward "goings-on" in enameling processes. It has been argued that we do not need to know these inward workings if we know how to make good enameled ware. It is the old argument of whether it is necessary or worth while for a driver to know anything about the mechanism of his car. Those who know say it is and those who do not know say it is not. Generally, however, when the driver who knows only the motions accidentally learns something about the mechanism he becomes an advocate of mechanical knowledge.

Perhaps a better illustration of the idea lies in the question of anatomy. A child or a primitive man gets along very well thinking the inside of his torso is just one big hollow space. I suspect that many an individual has lived to a ripe old age with that impression. No one in his right mind would contend that we are not better off now with the knowledge we have of the anatomy of the human body. And so in our own profession let us not forget these analogies nor think that our own case is an exception to the general rule.

With ours as in all other industries, greater demands are being made for refinement of product to suit special needs. Once two kinds of optical glass were sufficient for all needs. Now some fifteen or twenty are indispensible and as many more are desirable. At one time steel was steel, but now the exacting requirements of the consumer demand one specially prepared for each use. Uses for vitreous enamels are multiplying, and it behooves us to keep our technology up-to-date if we are to meet the demands as they come. The way to do that is to keep our research methods up-to-date by making the best possible use of new ideas and by being prepared to recognize a new idea when it appears.

WHAT HAS THE PAST ONE HUNDRED YEARS DONE TO THE BRICK BUSINESS IN THE U. S. A.?[1]

Some one recently dug up the records of the Lancaster, Ohio, School Board of 1828. In these records there is an account of a proposed debate as to whether railroads were practical or not. Permission was asked to hold the debate in the school house and the minutes of the school board were written as follows:

> You are welcome to use the school house to debate all proper questions in, but such things as railroads and telegraphs are impossibilities and rank infidelity. There is nothing in the word of God about them. If God had designed that His intelligent creatures should travel at the frightful speed of fifteen miles an hour by steam He would have foretold it through His Holy Prophets. It is a device of Satan to lead mortal souls down to Hell.

Not long ago a young man left New York on Friday morning, landed in Paris on Saturday evening, talked with his mother at Detroit by long distance telephone, and Monday morning newspapers in America carried a photograph of his landing in Paris which had been transmitted by radio and telegraph.

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[1] From the *National Bulletin*, "Weekly News Letter, No. 348," Common Brick Manufacturers' Association, June 11, 1927.

These two events give some hint of the progress of the last one hundred years. It would be a good idea for the brickmen to check up as nearly as possible what has been the progress in their industry during the last one hundred years.

We all know there has been marked progress in methods of manufacture, particularly in the last few years. It is greatly to the credit of the brick manufacturer that since 1922, when a period of prosperity set in, that a large proportion of the earnings have gone back into the business for extensions and improvements. There have been improvements in every department of the brick business, but there still is room for betterment, particularly in merchandising.

PAPERS AND DISCUSSIONS

APPARATUS THAT HAS IMPROVED OUR ENAMEL[1]

By L. S. Weimer

Batch Mixing

Mixing materials for the smelters has always been a problem, for no matter how thoroughly we tried to mix these materials we could always see the more fusible substances melt before the others. To overcome this difficulty a mechanical mixer of ample size to hold a smelter charge was sought; a concrete mixer was selected. Increasing the length twelve inches gave the required capacity, and a lighter machine than is used for the same volume of concrete. This mixer is provided with a tight cover so that no material is lost while mixing. It can be run at all different angles, thereby further assisting in securing a homogeneous batch.

The raw supplies are weighed and dumped directly in the mixer and at a 30° angle for ten minutes. This gives a thoroughly mixed batch. The batch is dumped into a hopper by tilting the mixer. It is then carried by an overhead crane and dumped into a rotary smelter.

Advantages Gained

Uniform frit, reduced fuel consumption, time of smelting reduced, and a whiter and more opaque white frit are among the advantages of this method. This more thorough mixing reduced the oil required for smelting from 56/1000 to 41/1000 gallons per pound of frit.

Spur Gear Mill Drive

It is desirable to have our enamel always milled uniformly fine. The pebble mill is slow speed compared with the motor used to drive it. If the speed is reduced by belts and pulleys there is so much slip and friction in the various reductions that it is practically impossible to obtain a constantly uniform speed. Revolution counters are used in some cases, but since the enamel mills differently at different speeds, it does not follow that the same number of revolutions produces the same degree of fineness.

A better way is to connect motor and mill by chains and external gears. While this gives good results, it generally is noisy, difficult to lubricate and has considerable power loss, due to friction.

To obtain uniform speed, reduce the noise, friction, and power loss we have a direct connected 4×5-foot mill with a spur gear speed reducer to a 5 H. P., 1200 r.p.m. induction motor. An induction motor is

[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich. February, 1927 (Enamel Division).

constant in speed for a definite load. There is no slip through the spur gear reducer. There is very little noise and friction as all gears run submerged in oil. The definite constant speed gives uniform fineness for a definite time run.

For this mill the manufacturers specified a 7½ H. P. motor, but it has been run for the past two years very satisfactorily by a 5 H. P. motor.

Uniform Enameling Heat

To fire the enamel properly was our next problem. By using a pyrometer we could control the temperature but it was difficult to consistently obtain a specified time-temperature heat treatment. Therefore an automatic timer was devised, so that each charge is fired exactly for a specified time. This instrument consists of a small induction motor with speed reduction so a hand may be set to an exact time interval. As the fork is run into the oven the timer automatically starts and runs for the desired time interval and then rings a gong. When the charge is removed from the oven, the timer automatically returns to zero. By this arrangement it is possible to obtain uniform firing and to eliminate the personal element.

Continuous Decorating

After firing, those white parts which are to be decorated are delivered to the transfer room. The tables are provided with electric heaters for drying the size and the washing tank with running water for removing the paper. An electric oven is used for drying the transfers before firing.

Panels are taken from the tank, dried carefully, and then placed on racks on a small truck. The truck holds 50 of the large size and 200 of the smaller panels. The car is run into the insulated oven. The oven is provided with three 1500-watt burners equipped with three-heat switches. The pieces are allowed to dry about 45 minutes at 400°, then they are taken from the other end of the oven to the furnaces for firing. As this is almost a continuous process it eliminates handling, decreases the time, dries in a clean oven accurate heat control, and reduces spoilage.

Summary

Summarizing, we have the raw materials taken from the bins, dumped into a mechanical mixer for thorough mixing, then run into a bucket when it is carried by trolley to rotary smelters. The frit is milled to uniform fineness by a direct-connected mill. The enamel is accurately weighed for dipping, and fired for a specified time controlled by an automatic timer, and then the transfer work is done by an electric oven.

Malleable Iron Range Company
Beaver Dam, Wis.

CONSUMPTION OF POWER IN THE HEAVY CLAY PRODUCTS INDUSTRY[1]

By S. Arthur Wills

Power application and supply are essential to a successful plant operation. When executives recognize the relative importance of this subject and give it its due consideration, then and only then are we going to accomplish control of this element in manufacturing.

The flow of raw material from its natural deposit to the finished product, even to the place of consumption, is literally a flow of power in one form or another. Is it not true that the relative importance of power application and source is eclipsed only by that of the raw material deposit itself?

Rarely, in the construction of clay products plants, has power application and its source been designed and constructed with the same relative degree of accuracy or knowledge as are the purely ceramic processes and equipment. Power is usually relegated to secondary importance and made to fit into the manufacturing process without sufficient thought and analysis. Plants in which a proper consideration has been given resulted in unit consumption of power and justified the attention.

Whenever an electrical power installation is planned by one whose knowledge in this particular line is limited, there are (1) underloaded motors, occasionally, overloaded, (2) voltage that will not permit of plant expansions, (3) high belt speeds, (4) poor speed ratios, (5) severe belting conditions, (6) incorrect motor types, etc., every one of which has a direct bearing on power consumption and therefore on costs.

A careful analysis in a firebrick plant disclosed poor motor application. They first had light load starting motors which could not start the imposed loads. These motors were replaced with larger ones of the same type which very easily started the loads. But, this plant is now much over motored and in consequence has poor operating efficiency and increased costs. Friction clutches with the smaller motors or motors of the same size but of a different type would have provided a correct solution. No one but the power company that is serving this plant gets the condemnation of such an experience because it is all reflected in the consumption of power. Complaint is made against high rates rather than against lack of forethought in application.

Several plants owned and operated by the same company have identical clay machinery driven by as many different sizes and types of motors as there are pieces of equipment. Certainly there is a correct size and type, and of the many different ones, surely they are not all on a par of

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[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., February, 1927. (Heavy Clay Products Division.)

excellence. Conditions vary in different plants and the right and merit of one plant superintendent to say "our conditions are unparallelled anywhere else" is recognized, but this is an excuse that is much overworked.

With proper investigation and coöperation much data can be secured that will lead to a more economical choice of power equipment application, and at the same time create a demand for improvement in equipment, design, and application.

Your business is the manufacture of clay products. Should anyone desire information relative to its uses he should consult you, not a power salesman. Likewise you, of the clay products industry desiring information relating to power and its application should consult those whose business is the sale and manufacture of power and power equipment. This apparent neglect of a fundamental item in your plan of manufacture is not caused by any desire on your part to produce the usual results obtained; but rather it is a failure to properly analyze its relationship to the production cycle and to consider it a controllable one. You will find the most glaring examples of these facts in plants where purchased power is used and in which a definite accurate cost of power can be obtained.

Purchased power service clearly defines unit power costs; there are no deferred charges, no left-overs; your monthly power billing gives this item. The purpose of your cost accounting system is to determine cost of the finished product; power is only an item therein and cannot be detailed as though it were the finished product. For this reason the true cost of power in an isolated power plant is very elusive, often indeterminate. Improved clay machinery, improved power unit application, careful analysis of load characteristics, and choice of motors to meet them, improved material handling methods, all are directly reflected more accurately and with more tangible results on purchased power. Power tariffs ordinarily provide this flexibility.[1]

You will perhaps not find another industry today in which a more earnest and dogged effort is being made to conserve natural resources than in the central station industry. Could an industry which has attained such far reaching economies in the generation of power stand idly by and see those economies wasted and lost in the utilization of that power, like pouring water through the bung-hole and running it out through the barrel head?

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[1] I know of firebrick plants using from 20 to 48 kw. hr. per M. bricks produced, and face-brick plants using from 19 to 64 kw. hrs. It therefore does not follow that all plants should be the same; there are many variables that affect power requirements. Let me caution you in your friendly comparing of notes on power consumption and costs that you analyze very carefully all conditions that may affect power consumption.

The power industry has thoroughly trained men in industrial power and lighting service who are always at your call. Make use of them; do not ignore them. They know best the relation of power tariffs to your manufacturing processes, and what effect this or that type of equipment has upon purchased power costs. Consult a power engineer; do not ask your friend, his conditions may be entirely different; do not ask your power plant operator, he may be prejudiced.

We do not claim to be more patriotic in the conservation of our nation's resources than any other industry, but primarily we are engineers and the axiom of any good engineer is practical efficiency. What then must be the power companies' attitude toward inefficiency in their customers' plants? We do not attempt to sell power service where we know to do so would not be the practical or economical thing to do. Very often the industrial plant executive will not analyze his power service requirements with an open mind, consequently he is more apt to be misled than with those elements of his manufacturing process in which he is thoroughly trained. Power service requirements can no more be decided by rule of thumb than can the manufacturing process itself.

We view the AMERICAN CERAMIC SOCIETY as a vehicle which carries the idea of advanced power application and supply. It has access to all individual enterprises. It can secure a comprehensive analysis of the power problem in the whole industry whereas any other agency could analyze only individual cases which may or may not be representative of the whole industry.

We see this SOCIETY as the hub in a coöperative movement for the improvement of power application in your industry, the manufacturers of clay machinery, electrical equipment, and electric power (the power company itself) as the coöperators for the common good of all. Four years ago we were ridiculed for proposing the electric drive for a sewer pipe press but today, through the coöperative efforts of these people, a press has been designed from accurate duty cycle tests. It will very shortly be installed in a pipe plant for trial.

It cannot be done, you will say; we need steam for drying, why use electricity? It can be done, with a great reduction in investment and labor by combining low pressure steam drying and purchased electricity.

A 50-horsepower motor will operate one of the largest pipe presses and not use that power continuously. Picture then the present pipe plant with its 300 or more horsepower in boilers, big coal pile, several firemen, and an engineer, large press gang, steam belching forth every few seconds unexpanded in the cylinder and roaring its "chug-chug-chug-chug-g-g" in dollars of waste. Then picture the new plant using purchased electric power with a 50-horsepower boiler for drying, no

regular firemen, no engineer, reduced press gang, semi-automatic operated press and no dollars going out the stack or the exhaust, and perhaps 50% the investment.

Such a picture is no dream. The power company positively was the principal factor in creating the demand for this design, and in conducting tests.

Summary

The principal points herein emphasized are (1) power supply and application is an essential in ceramic industries; (2) importance of power costs prompts one to analyze and design the equipment thoroughly and intelligently; (3) accept the principle of specialized endeavor; go to the power company for help on the power problem; (4) the opportunity for coöperation between the AMERICAN CERAMIC SOCIETY, the machinery manufacturer, the electric machinery manufacturer, and the power company is before you.

APPALACHIAN ELECTRIC POWER COMPANY
HUNTINGTON, W. VA.

DISCUSSIONS ON CERAMIC EDUCATION[1]

Is the ceramic engineer as at present being turned out by the departments of ceramic engineering satisfactorily serving the refractories industry? In what respect is his training lacking?

JOHN L. GREEN: In justice to the various departments of ceramic engineering I do not think they are trying to turn out men especially equipped to serve the refractories industry. They are endeavoring to so train their students that they may enter any branch of ceramics and that means they can only give them in the time allowed, a very general grounding in the subject. It is a far cry from refractories to the china industry, or the manufacture of terra cotta, or the enamel of metals.

It is my belief that the departments of ceramics should try and have their students decide on the branch of ceramics they intend to take up and then give them the work to fit them specially for that branch of the art. I believe, therefore, that the ceramic engineering schools could better serve the industry by stressing less general engineering subjects with a view in mind of training the student as a technologist rather than as an engineer. Such subjects as chemistry, physics, geology, mineralogy, and petrography could well be stressed in place of surveying structural design and thermodynamics. It should be realized that all students are not adapted for straight research work

[1] Presented at a meeting of the American Refractories Institute, Atlantic City, N.J., May 18–19, 1927.

and perhaps the matter might be best handled by arranging the curriculum to allow for alternate courses of study as fitted the student.

I think further attention should also be given to instilling in the student a sense of business ethics and training. Engineering English should, of course, retain its present prominent position in order that proper expression may be formed for making record of later achievements.

If a course of study is to be arranged which would be a specialized one in refractories, the study of glaze compositions might well be eliminated in favor of furnace designs, heat transmission and other subjects mentioned above.

LACLEDE-CHRISTY CLAY PRODUCTS CO.,
ST. LOUIS, MO.

BY G. H. DIACK: So much depends on the individual, upon the man himself, that it is difficult to say whether or not the ceramic engineer as at present turned out is satisfactorily serving the refractories industry. There are, no doubt, cases of failure, as in other lines, and on the other hand some men, graduates in ceramic engineering, have made enviable successes in refractories.

The present curricula of ceramic colleges, in my opinion, do not train men especially for refractories; neither do they for white ware, terra cotta, or any of the other phases of the ceramic industry; in fact, their attempt is to equip the man with a more or less rounded knowledge of the fundamentals of the whole industry, and a great deal depends upon the young graduate whether or not he will be able to adapt himself to any particular field, and to apply what knowledge he may have regarding that field and, after and above all, acquires new knowledge as he goes along so that he will be of real service to his employer and to the particular industry he has chosen. In fact, I believe the university should strive to do just that, that is, to so broaden the man that he can adapt himself to any specialized field, teach him to study and to keep abreast of the new things in his work, because, after all, most of the actual facts pertaining to the ceramic industry that one learns in college are relatively soon, at least, obsolete. This is no doubt equally true in any line of work. It was said recently that if "we believe today, the things we believed last year, we are slipping" which may be slightly exaggerated but yet contains quite an element of truth.

However, regarding the latter part of the question under discussion a great deal may be said. To serve the refractories industry specifically, no doubt quite a lot is lacking in the ceramic graduate's course of study. Were he able to apply all the time and effort he must spend upon the work designed to acquaint him with the other fields in ceramics, upon

subjects bearing more directly upon refractories, he no doubt would come out much better equipped to serve the industry and to meet its problems. More time could be given to the study of chemistry at high temperatures as well as the study of refractories in service, a thing which to me seems very important, and yet is practically untouched in most ceramic schools. The young graduate entering the refractories field knows very little of the conditions of service under which his product is going to be used and necessarily works rather blindly until time has given him opportunity to learn them after leaving college. Moreover, more time could be devoted to laboratory work in refractories so that the student could become more familiar with the tests, both practical and of an experimental nature, with which he would later become concerned. The refractories industry is so linked with metallurgy, power, and all industries involving high temperatures that it seems almost necessary to devote as much time as possible to their study in order to equip a man to serve our industry best.

In considering such a thing as this another enormous question looms up, "Can the colleges prescribe specialized courses for all the many phases of ceramics?" There would be at least seven or eight, because what has been said above concerning refractories is equally true, in the same sense of glass, enamels, white ware, and all the other branches of the ceramic industry. Further than this, each subject might be divided into two more phases, at least, from a teaching standpoint, depending on whether or not the student wishes to enter into research work or into the practical field of manufacturing, because a different training, in fact, even a different attitude or frame of mind is needed to be most efficient in either line.

It is almost impossible to solve the answer to this last question on account of the student himself, because he rarely does and seldom ever can decide what his chosen field of endeavor will be until the very latter part of his college career, in many cases, his last year when it is too late to do much specialization.

So it seems, therefore, that the universities and colleges teaching ceramics should make special effort that the student be firmly grounded in the fundamentals of ceramics as well as those of mathematics, English, and other things which are necessary to conduct the man successfully through life, require him to spend some time in the practical operation of a chosen field in ceramics, and to instil in him the ideals of integrity, honesty, and right living to carry on. I believe if it be possible to do these things, the man will be able to serve any branch of ceramics successfully provided he has right stuff in him, and there would be no serious lack in his training.

ACTIVITIES OF THE SOCIETY

AMERICAN CERAMIC SOCIETY MEETINGS

Meeting together is essential for exchanging of ideas, for strengthening personal relations, and to mutually inspire and give courage.

It is axiomatic that progress in human affairs is made when people work *with* one another and that human affairs are hindered rather than progressed when people work *for* one another.

If people are to work *with* one another they must know one another. Those who do not attend the Meetings of this SOCIETY are failing to do their part in the great coöperative work for which the members of this SOCIETY are associated.

Here are three occasions to work with your fellow ceramists:

(1) **Fall Meeting.** Grand Central Palace, New York City. Chemical Exposition, Thursday, September 29, 1927.

(2) **Annual Meeting.** Ambassador Hotel, Atlantic City, February 5 to 11 incl., 1928. The National Brick Manufacturers will meet concurrently.

(3) **European Tour.** Six weeks tour abroad with the ceramists of England, Germany, Czechoslovakia, France, and Holland.

MEMBERSHIP RECORD

Not all folks continue in a given vocation. Each person seeks for the work in which he will find the most pleasure and profit, the one to which he is most adaptable. Thank goodness, not every person, nor even many persons try to find their life work in ceramics.

Records show that 90% of those who studiously decide to make ceramics their life work are finding it sufficiently profitable and pleasant. It calls for such a varied personal adaptability that any one who wills to do so, may find in ceramics as much joy and profit as he would in any other activity.

But in opportunities for self-expression and profit, ceramics differs in no wise from any other vocation and here lies the reason for the comparatively large membership turnover which this SOCIETY experiences each year.

The new members received each year have more than offset the resignations and disappearances; the number of those who are enlisting in this coöperative work of promoting the science, art, and technology of ceramics is steadily increasing.

Because manufacturing resourcefulness and progress is dependent on knowledge of the fundamentals, and on their application in ceramic art and technology, there is a general awakening to the fact that it pays to have such an organization as this SOCIETY. The larger it is the larger will be the returns in knowledge and in facilities for obtaining knowledge. Those who have contributed to the SOCIETY's growth during the past six months are listed on pages 242–43.

NEW MEMBERS RECEIVED FROM JUNE 1 TO JULY 1

CORPORATION

R. Gaertner & Co., Inc., 200 Fifth Ave., New York City, and East Liverpool, Ohio. Rudolf Gaertner, representative.

PERSONAL

***W. E. Buck,** 3710 Vista Pl., Pine Lawn Blvd., St. Louis, Mo.

Samuel J. Carnes, President, Camden Art Tile & Pottery Co., Camden, Ark.

Harold S. Dunn, Harbison-Walker Refractories Co., Portsmouth, Ohio. Salesman.

Fr. Eissenloeffel, 3452 First Ave., Long Island City, N. Y. Chemical Engineer.

Leo J. Franz, 214 E. Monroe St., Mexico, Mo. Ceramic Engineer.

* Renewal

†**G. E. Fraunfelter,** Fraunfelter China Co., Zanesville, Ohio.
Marcus Ginsburg, 9630 Greeley Ave., Detroit, Mich. Peninsular Stone Co.
Nathaniel J. Kent, Hotel Asbestos, Manville, N. J. Ceramist, Johns Manville Corp.
Maurice C. Lloyd, c/o Eliza Tinsley Pty., Ltd., 644 Bourke St., Melbourne, Australia.
Sidney H. Pinsent, Florida 32, Buenos Aires, Argentine. Gen. Manager and Engineer, "Ferrum" S.A. & Allied Companies.
***L. I. Shaw,** Western Electric Co., Hawthorne Station, Chicago, Ill.

*Renewal
†Transfer of membership

STUDENT

James R. Beam, 126 Gaius St., Bucyrus, Ohio.
Wen-Wai Huang, 30 Chittenden Ave., Columbus, Ohio.

Membership Workers' Record

	CORPORATION		PERSONAL
Lois W. Rhead	1	G. Carlisle	1
		C. F. Geiger	2
	STUDENT	F. A. Harvey	1
Kai-Ching Lu	1	C. A. Smith	1
Office	1	H. G. Wolfram	1
	—	Office	5
Total	2		—
		Total	11
	Grand Total		14

MEMBERSHIP WORKERS' RECORD FROM DEC. 16 TO JULY 1, 1927

	CORPORATION		PERSONAL
G. Blumenthal	1	W. N. Harrison	1
E. deF. Curtis	1	F. M. Hartford	2
V. G. Green	1	F. A. Harvey	1
R. A. Horning	2	S. E. Hemsteger	1
W. F. King	1	E. C. Hill	1
J. D. Martin	1	F. E. Hodek, Jr.	1
Lois W. Rhead	1	J. W. Hoehl	3
F. H. Riddle	1	B. M. Hood	1
D. F. Stevens	1	R. K. Hursh	1
T. C. Walker	1	J. E. Hutchinson	1
Office	7	M. Ichijo	1
	—	W. V. Knowles	3
Total	18	T. N. Kurtz	2
	PERSONAL	R. D. Landrum	1
H. Akermann	1	F. E. Lauer	1
M. G. Babcock	1	J. B. Lyon	1
H. Brewer	2	P. S. MacMichael	1
D. Brown	1	A. T. Malm	1
T. G. Brown	1	H. W. Mauser, Jr.	1
P. P. Budnikoff	1	W. K. McAfee	1
G. Carlisle	1	G. V. McCauley	2
W. M. Clark	1	C. B. McComas	1
J. L. Crawford	1	T. N. McVay	1
E. deF. Curtis	6	C. H. Modes	1
W. A. Darrah	1	D. A. Moulton	1
K. H. Endell	1	F. P. Nickerson	1
F. C. Flint	1	J. P. Nikonow	2
V. Foster	1	C. L. Norton	1
D. B. Fraser	1	A. C. Ochs	1
M. L. Freed	1	R. J. Paddock	1
B. Frosterus	1	C. W. Parmelee	1
C. F. Geiger	4	H. G. Parsons	1
E. E. Geisinger	1	S. M. Phelps	1

	Personal		Student
E. E. Pressler	1	A. I. Andrews	4
F. H. Rhead	1	G. A. Bole	1
E. Schramm	1	C. M. Dodd	1
D. D. Schurtz	1	A. F. Greaves-Walker	1
M. A. Schweiker	1	A. V. Henry	14
R. F. Sherwood	1	R. K. Hursh	5
C. A. Smith	1	W. A. Koehler	1
D. F. Stevens	1	Kai-Ching Lu	1
M. C. Stratton	1	S. Matthews	2
S. D. Swan	1	T. N. McVay	1
B. T. Sweely	1	D. A. Moulton	2
C. F. Tefft	1	C. W. Parmelee	4
W. E. S. Turner	1	J. B. Shaw	2
E. J. Vachuska	1	T. W. Talwalker	1
W. H. Vaughan	1	E. J. Vachuska	2
T. C. Walker	1	A. S. Watts	1
R. T. Watkins	1	F. Westendick	19
F. Whitehead	1	H. Wilson	2
H. Wilson	1	Office	12
H. G. Wolfram	1		
E. Zschimmer	2	Total	76
Office	40		
		Total New Members	225
Total	131		

PERSONAL NOTES OF MEMBERS

The address of the **Associated Tile Manufacturers** has been changed from Beaver Falls, Pa., to 220 Graybar Bldg., 420 Lexington Ave., New York City.

Earl R. Curry has moved from Lincoln, Calif., to Willoughby, Ohio.

Thomas M. Felton writes that his new address is 1416 Dormont Ave., Pittsburgh, Pa. Mr. Felton has been an instructor in the Department of Ceramic Engineering at Ohio State University during the past year.

H. D. Foster, formerly of the Bureau of Standards, Washington, D. C., has moved to 266–13th Ave., Columbus, Ohio, having accepted a position with the Ohio Ceramic Industries Association.

Robert Galbraith, recently associated with the American Terra Cotta and Ceramic Company at Crystal Lake, Illinois, has moved to 502 West Fifth Ave., Pine Bluff, Arkansas.

Edward L. Harcourt is living at 909 Lexington Ave., Zanesville, Ohio. Mr. Harcourt is carrying on research work at the Ohio State Prison Brick Plant at Roseville, Ohio, an activity of the Ohio State University Engineering Experiment Station.

Perry D. Helser has removed to Ford City, Pa., c/o Eljer Company. Mr. Helser formerly was associated with R. Thomas & Sons Co., Lisbon, Ohio.

George F. Hersey, formerly in Los Angeles, Calif., is now employed with the American Resistor Corporation of Milwaukee, Wisconsin.

A. H. Kuechler, who has been assisting with research problems at the Missouri Engineering Experiment Station, is now with the Physical Laboratory of the U. G. I. Contracting Company. Mr. Kuechler's address is 2720 N. 11th St., Philadelphia, Pa.

John S. Lathrop, formerly associated with the Gladding, McBean & Co., Lincoln, Calif., is now with the California Clay Products Company of Southgate, Calif.

F. W. Miller of the Carborundum Company has moved from Philadelphia to 56 Cedar Ave., Newark, N. J.

Ellsworth P. Ogden has resigned his position with E. J. Lavino Company, Philadelphia, and has removed to 1957 Chelsea Rd., Columbus, Ohio. Mr. Ogden is interested in the manufacture of California stucco for interior and exterior decoration. A company for the manufacture of this material is now being organized.

Burton E. Peck is located at Hobart, Indiana, c/o National Fire-proofing Company.

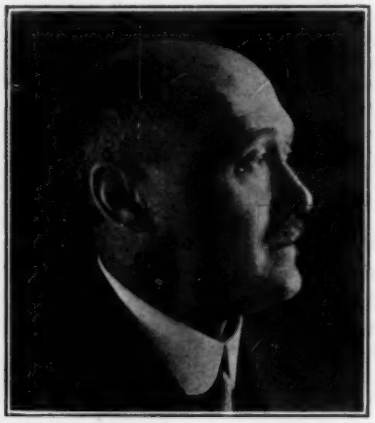
H. A. Rossell, formerly of Spruce Pine, N. Car., Tennessee Mineral Products Company has moved to Santa Rita, N. Mexico, Box 212.

T. A. Shegog has moved from East Liverpool, Ohio, to 713 N. Broadway, Baltimore, Md. Mr. Shegog is now associated with the Edwin Bennett Pottery Company, 600 S. Eden St., Baltimore, Md.

Murray Sinclaire, of H. P. Sinclaire & Co., has moved from the Dunkirk, N. Y. to the Corning, N. Y. plant of the same Company.

W. D. Turner, of the Chemistry Department, Univ. of Missouri, Rolla, Mo., is now located at Havenmeyer Hall, Columbia Univ., New York City.

Bruce F. Wagner has moved from Cleveland, Ohio, to Berwyn, Illinois, Apt. No. 105, 6914 West 21st St.



EDWARD C. STOVER

S. F. Walton of the Robert Y. Bernard Company, Philadelphia, Pa., is now located in Blasdell, N. Y., where he is associated with the Exolon Company.

Harold E. White of the Federal Abrasives Company, Anniston, La., is now employed by the Lava Crucible Company of Pittsburgh, at Zelienople, Pa.

OBITUARIES

Edward C. Stover

Edward C. Stover, charter member of the AMERICAN CERAMIC SOCIETY, died on July 10, 1927, at Trenton, N. J. He served as president of the SOCIETY during 1903–1904. Mr. Stover, for more than twenty-five years was Treasurer of the School of Industrial Arts of Trenton. He was a charter member of the Society Ceramique of France, and also of the English Ceramic Society of the Staffordshire pottery district of England. When the Collected Works of Herman Seger were published, Mr. Stover acted as chairman of the publication Committee.

I. M. Justice

Ithamar M. Justice died on June 23, 1927, at his home in Dayton, Ohio. He was vice president of the Manufacturer's Equipment Company at the time of his death. This company has expanded so rapidly from the time of its organization that it has been known to many as manufacturers of driers and other brick equipment.

I. M. JUSTICE

A practical brick maker, an experienced school teacher, and an inventor of no mean ability, Mr. Justice was highly successful in designing equipment for specific purposes and in securing opportunities to work out his ideas on plants. As a developer and sales promoter he was also successful. Cheerful always,

harboring no ill will, always loyal and straight forward, Mr. Justice won a large place in the hearts and memories of American brick manufacturers.

Mr. Justice was a member of the AMERICAN CERAMIC SOCIETY and of the National Brick Manufacturer's Association for several years. He was a frequent contributor to meeting programs and always a booster for education and research, aiding greatly in advancing the objectives of these two organizations.

Mary Anderson Orton

Mary Anderson Orton, wife of General Edward Orton, Jr., died on July 9, at her home, 788 East Broad Street, Columbus, Ohio, after a protracted illness. She was the daughter of the late Judge James H. Anderson and Princess A. Miller, and was born in Marion, Ohio, Aug. 26, 1857.

When a little girl of 3 years, her father was appointed consul to Hamburg, Germany, and her earliest recollections were all of the life there, from which she returned at the age of 8 years. Her parents then lived at Mansfield, Marion, and Upper Sandusky, successively, until, in 1874, Judge Anderson came to Columbus and opened a bank at No. 6 East Broad street.

MARY ANDERSON ORTON

She had a fine literary taste and was a wide reader, which led to her becoming an organizer and active worker in several literary clubs, which were the precursor of the numerous women's clubs of the present day.

In 1888, she married Edward Orton, Jr., then a young mining engineer, and went with him to various places where his work took him, living successively in New Straitsville, Ohio, Goshen Bridge, Va., and Gloverport, Ky. In 1894, her husband was appointed to a place in the faculty of the Ohio State University, and from that time they established their permanent home in Columbus.

Mrs. Orton soon interested herself actively in the Daughters of the American Revolution. She worked vigorously and steadily for that organization, becoming state regent of Ohio, and later a national officer. Her most important contribution in this organization was the preparation of the large annual report of the society to the Smithsonian Institution, which she did for four consecutive years. She was also interested, though to a less degree, in other genealogical societies and historical societies. In the long years of struggle for woman suffrage, she took an active part.

After the death of her father and mother, in 1912 and 1913, Mrs. Orton remodeled the old family home and moved into it on Thanksgiving day, 1914. She had just returned from a trip to Europe, where she and her husband had been caught in the meshes of the World War, a few days after they landed in Germany. Overseas, it was impossible to

get authentic information, but in the United States again she studied every document she could get as to causes and reasons for the war, finally giving her complete sympathy to the allies, in spite of her deep love and affection for the Germany which she knew as a child.

When her husband was commissioned in the army in May, 1917, she took up organization work on bond sales and war saving stamps sales and worked with great activity and effectiveness.

She was cut down by a heavy stroke of paralysis on Feb. 12, 1919, while with her husband in Washington. He brought her back to her home in June, 1919, as soon as he could obtain his discharge from the army. She never made any headway toward recovery. Her life for the past eight and a half years has been one of complete helplessness and great suffering, and death can be considered in no other light than as a merciful release for her.

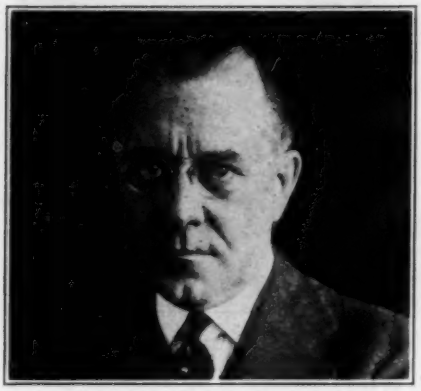
She was the last surviving member of her immediate family.

Mrs. Orton was of a bright, vivacious disposition; a vigorous, energetic worker for whatever cause she took up; a positive, determined mentality with clear-cut, definite convictions and the courage to express, and, withal, an intensely loyal and loving nature that elicited the best from others to whom she gave her friendship.

NOTES AND NEWS

FRANK G. HOLMES WINS MEDAL

Frank G. Holmes, designer for Lenox, Inc., Trenton, N. J., was recently awarded the Craftsmanship Medal for distinguished achievement in ceramic art by the American Institute of Architects. The medal was presented to Mr. Holmes at a meeting by the Institute in the United States Chamber of Commerce auditorium, Washington, D. C. on May 13, 1927, in connection with the sixtieth meeting of the Institute.



FRANK G. HOLMES

Mr. Holmes began his art studies when a boy twelve years old in the evening classes of the public schools of Pawtucket, R. I. At sixteen years of age he studied for one year at the Rhode Island School of Design of Providence, R. I., and later he was apprenticed in the designing room of a silver factory continuing his art study in night classes.

In 1901 Mr. Holmes was employed in the designing room of Dominick and Hoff, a silverware concern in New York City. During the five years at this factory he continued his art study in the night classes for the old New York School of Art under Robert Henri and Frank Dumond. For one year he taught design in evening classes of Pratt Institute, Brooklyn.

In 1905 Mr. Holmes became affiliated with Lenox, Inc. He was appointed by Herbert Hoover as one of the three commissioners to visit and report upon the International Exposition of Modern Decoration and Industrial Art in Paris.

Mr. Holmes' paper on "The Advantage of Good Design in Tableware" was published in the *Bulletin of the American Ceramic Society*, July issue, pages 181–83.

FIELDNER MADE SUPERINTENDENT OF BUREAU OF MINES STATIONS

Arno C. Fieldner, superintendent of the Pittsburgh Experiment Station of the United States Bureau of Mines, Department of Commerce, has been appointed to the position of Chief Engineer, Division of Experiment Stations, of the Bureau, effective July 1. In his new position, Mr. Fieldner will correlate the scientific activities of the Bureau's experiment stations located at Pittsburgh, Pa., Salt Lake City, Utah, Reno, Nev., Berkeley, Calif., Tucson, Ariz., Seattle, Wash., Bartlesville, Okla., Rolla, Mo., Minneapolis, Minn., Birmingham, Ala., and New Brunswick, N. J. At these experiment stations problems dealing with the elimination of waste in the different mineral industries are being studied.

Mr. Fieldner, who has served as superintendent of the Pittsburgh Experiment Station for the past six years, is rated as one of the Bureau's outstanding research specialists. He is regarded as an authority on the technology of coal, coke and gas, and ventilation problems, involving noxious gases, in mines, tunnels and elsewhere.

ARNO C. FIELDNER

Mr. Fieldner, a native of Ohio, was born December 12, 1881. He was graduated in chemical engineering at Ohio State University in 1906. In 1907, he joined the staff of the United States Geological Survey and with that organization and later with the Bureau of Mines engaged in research, performing notable work in connection with the utilization of coal, coke, petroleum, and other fuels.

During the World War, Mr. Fieldner served as a major in the Chemical Warfare Service, and was placed in charge of gas mask research. The methods developed by him for testing the efficiency of gas masks and absorbents were generally used by the Chemical Warfare Service and were later adopted by some of the laboratories of the Allies.

While serving as superintendent of the Pittsburgh Experiment Station of the Bureau of Mines, Mr. Fieldner's interests widened from fuels and gas to research on safety in mines, metallurgical and industrial establishments, and health problems in the mining and allied industries. He organized and directed the exhaustive research work of the Bureau of Mines in coöperation with the New York and New Jersey Tunnel Commission on the combustion of automotive exhaust gases and the minimum safe concentration of carbon monoxide in tunnel atmospheres. The professional degree of chemical engineer was conferred on him in 1923 by Ohio State University in recognition of this work.

In 1924, Mr. Fieldner spent six months in visiting European laboratories and industries, studying especially the carbonization and processing of coal, and safety in mines research.

Mr. Fieldner has, for a number of years, been chairman of the Committee on Coal and Coke of the American Society for Testing Materials, has twice been chairman of the Chemical Committee of the American Gas Association, and is a continuing member of the Managing Committee of the Technical Section of this organization. He has served as chairman of the Gas and Fuel Section of the American Chemical Society and is now a member of the Executive Committee. He likewise is a member of the Committee on Coal and Coke of the American Institute of Mining and Metallurgical Engineers, is a

past chairman of the Steel Works Section of the Engineers' Society of Western Pennsylvania, and is an active member of the Coal Mining Institute of America.

Mr. Fieldner has contributed a large number of articles to the scientific and technical press and is the author of a long list of bulletins and other publications of the Bureau of Mines. Two years ago he was invited to become a member of the Coal Research Club of England.

A few of his most important publications are as follows:

Bureau of Mines, *Bull.*, Nos. 22, 85, and 123 on "Analyses of Coals of the United States"; *Bull.*, No. 129, "Fusibility of Coal Ash and the Determination of the Softening Temperature"; Bureau of Mines, *Tech. Paper*, No. 8, "Methods of Analyzing Coal and Coke"; *Tech. Paper*, No. 144, "Quick Determination of Incombustible Matter in Coal and Rock-Dust Mixtures in Mines"; *Tech. Paper*, No. 262, "Permeation of Oxygen Breathing Apparatus by Gases and Vapors"; *Tech. Paper*, No. 396, "Low-Temperature Carbonization of Coal"; "Experimental Studies on the Effect of Ethyl Gasoline and its Combustion Products"; "Ventilation of Vehicular Tunnels"; "Practical Value of Fundamental Research on Coal," Proceedings of International Conference on Bituminous Coal, Carnegie Institute of Technology, November, 1926; "Future Trends in Automotive Fuels," *Ind. Eng. Chem.*, October 1, 1926; "Trends in Power Plant Development," *Ind. Eng. Chem.*, October 1, 1926; "Complete Utilization of Coal and Motor Fuel," *Blast Fur. Steel Plant*, March, 1926.

NOTES FROM THE CERAMIC SCHOOLS

Iowa State College

Three men took the degree of B.S. from the Department of Ceramic Engineering at Iowa State College at the end of the year 1926–27. Homer M. Tostlebe is employed in the sewer pipe plant of the Evens and Howard Fire Brick Co., in St. Louis.

Howard M. Parkhurst is an understudy to the general superintendent of the Utah Fire Brick Co. at Salt Lake City, Utah.

La Verne N. Gill, who will complete his work at the end of the first summer session in July, will be employed by the Standard Sanitary Manufacturing Co. at San Pablo, California.

The Benjamin Electric Co. at Des Plaines, Illinois, employed nine of the undergraduates of the Department for summer employment in the enameling department. Most of the undergraduates have found employment for the summer in ceramic plants. One or two will go to the Black Hills of South Dakota for the summer trip with the Department of Geology, to study geology.

The department numbered 43 at the end of the year's work. Two of these are girls who expect to develop themselves for research laboratory workers. The indications are that a large number of men now enrolled in the overcrowded electrical engineering department will change to ceramic engineering this coming year, and probably the freshman class will equal the one of this year so that it is reasonable to expect an enrollment of close to sixty next year.

A new recording instrument of the Brown Instrument Company make, a frit furnace of student design and construction, and a number of new pieces of small apparatus, have been added to the equipment.

Two hundred girls from other departments took work in modelled pottery and work is well under way toward the completion of a tile and terra cotta fire place decoration, a memorial to the soldier dead, which is to be placed in the new Memorial Union Building which is in process of construction at this time on the Ames campus. This is faculty work and a donation to the Memorial Union by the Department. Numerous exhibitions

of Ames pottery were made both in Iowa and outside of Iowa, and favorable interest in Iowa shales was aroused thereby.

Research work is being carried on alone by D. A. Moulton. His present problem is to prove up Iowa materials for roofing tile manufacture. Work of this nature is requested from the Department by the Engineering Experiment Station. Iowa needs factories and it is to satisfy this need that Prof. Moulton's energies are directed.

Robert L. Blessing who was graduated last June is with the Mellon Institute group working on sewer pipe kiln burning problems.

North Carolina State College

The first graduates of the Department of Ceramic Engineering at North Carolina State College received their degrees at the recent commencement. The men graduating were L. R. Whitaker, Camden, S. C., E. R. Walsh, Louisville, Ky., and E. N. Brackett, Landrum, S. C. Both Whitaker and Walsh held degrees of B.S. in Chemistry before entering North Carolina State.

Whitaker has accepted a position as Ceramic Engineer with Moland-Drysdale Corporation, Hendersonville, N. C., one of the outstanding clay products companies of the State. He will take charge of the development of the new line of buff face brick and hand made roofing tile.

Walsh has taken a position with the Clay Products Association Kiln Research crew and is located at the plant of the Pomona Terra Cotta Company, Pomona, N. C.

Brackett has been employed by the Taylor, Smith and Taylor Company of Chester, West Virginia on the construction of their new Harrop kiln.

It is especially pleasing to the College and Department that these first graduates were located in positions south of the Mason and Dixon line.

The Department at North Carolina State College expects to have considerable new equipment installed during the summer. This will include among other items, a number of blungers, several new ball mills, a crusher, and a coal fired kiln.

Ohio State University

The graduates of the Ceramic department, Ohio State University, have been placed in situations since their graduation as follows:

Raymond Birch, Carlyle Labold Co., Portsmouth, Ohio
A. J. Blume, connection to be announced later.
V. E. Campbell, Homer Laughlin China Co., Newell, W. Va.
F. B. Carter, Standard Sanitary Mfg. Co., Tiffin, Ohio
K. M. Y. Chiu, going to Europe for additional study.
Paul Collins, Research Fellowship—Ohio State University
R. S. Craft, Findlay Clay Pot Co., Washington, Pa.
R. W. Craig, connection to be announced later.
C. M. Dodd, Robinson Clay Products Co., Akron, Ohio
J. H. Grady, Gladding McBean & Co., Los Angeles, Calif.
E. C. Guisinger, Mt. Clemens Pottery Co., Mt. Clemens, Mich.
E. L. Harcourt, Eng. Experiment Station, Ohio State University
C. P. Layton, Layton Brick Works, Marion, S. C.
J. H. Lumley, to return for graduate work
R. W. MacDonald, National Fire Proofing Co., E. Palestine, Ohio
G. H. Merry, Beldon Brick Co., Canton, Ohio
J. H. Rolke, Harrop Ceramic Service Co., Columbus, Ohio

W. H. Schotts, Harrop Ceramic Service Co., Columbus, Ohio
P. F. Siegrist, Robinson Clay Products Co., Akron, Ohio
A. L. Simison, Winslow Glass Co., Columbus, Ohio
W. M. Taylor, Tycer Pottery Co., Roseville, Ohio
R. H. Aldridge, (special) Mount Savage Fire Brick Works, Mt. Savage, Md.

Pennsylvania State College

Monroe L. Wexler of Philadelphia is employed by the Production Department of the Precision Grinding Wheel Company at Philadelphia.

Joseph E. Weis of Scranton, Pa., is a ceramist in control of raw material for enamels for the Mansfied Vitreous Enameling Co., (subsidiary of the Westinghouse Electric and Manufacturing Company) Mansfield, Ohio.

Frederick B. Holmes of Harrisburg is employed by the National Fireproofing Company, Perth Amboy, N. J.

Walter A. Preische who has been instructor of this department for 2 years has secured a position with the Universal Sanitary Manufacturing Company of New Castle, Pa. His work will be largely of research and development character.

George J. Bair, Emporium, Pa., not decided.

University of Missouri School of Mines and Metallurgy

The laboratories of the Missouri School of Mines and Metallurgy Ceramic department will be equipped for Junior ceramic work. An increase in enrollment of some fifteen students will be provided for the coming school year. The work of the clay testing and research laboratory which is operated in conjunction with the Ceramic Engineering Department, will be expanded, the funds derived from that work being applied to the purchase of needed laboratory equipment.

A. J. Paul will be transferred from the laboratory to the Ceramic Engineering Department, as instructor in Ceramics, at least on part time.

University of Washington

Henry N. Baumann was the only man from the Ceramic Department to be graduated in June from the University of Washington. Mr. Baumann received both his Master's degree in Mining Engineering and Bachelor of Science in Ceramics. His thesis work in coöperation with the U. S. Bureau of Mines on "Heat Balance of Ceramic Kilns" will be published soon in the *Journal of the American Ceramic Society*. Mr. Baumann has been employed since the first of the year with the Carborundum Company at Niagara Falls, N. Y.

BRICK MANUFACTURERS ASSOCIATION STUDY DRYING CONDITIONS IN COMMERCIAL DRIERS

A field party engaged in making a study of the drying conditions in commercial driers in the interests of the coöperative investigation being carried on under the auspices of the Research Committee of the National Brick Manufacturers Association and the Department of Ceramic Engineering, University of Illinois, Urbana, Illinois, after several months in the Acme Brick Company's plant at Cayuga, Indiana, has moved to the plant of the Crawfordsville Brick Company, Crawfordsville, Indiana. Some very interesting and valuable data has been obtained by the plant studies which are being conducted in conjunction with laboratory investigations.

CALENDAR OF CONVENTIONS

Amer. Assn. for the Advancement of Science	Dec. 28–31, 1927	Nashville, Tenn.
AMERICAN CERAMIC SOCIETY Annual Meeting	Feb. 5–11, 1928	Atlantic City, N. J.
American Chemical Society	Sept. 5–10, 1927	Detroit, Mich.
American Concrete Institute	Feb. 28–Mar. 1, 1928	Philadelphia, Pa.
Amer. Electrochemical Soc.	Sept. 4–20, 1927	Trip through Northwest
American Engineering Council	January, 1928	Washington, D. C.
Amer. Gas Association	Oct. 10, 1927	Chicago, Ill.
Amer. Inst. Mining and Met. Engrs.	February, 1928	New York City
Amer. Mining Congress	1st week Dec. 1927	Washington, D. C.
Amer. Refractories Institute	Sept. 15, 1927	Niagara Falls, Can.
Amer. Soc. Mechanical Engrs.	Dec. 5–8, 1927	New York City
Amer. Soc. Steel Treating	Sept. 19–23, 1927	Detroit, Mich.
Assn. Chem. Equipment Mfgrs.	Sept., 1927	New York City
Ceramic Soc. of England	Sept. 26–27, 1927	Bournemouth, England.
Exposition of Chem. Industries	Sept. 26–Oct. 1, 1927	New York City
Hollow Building Tile Assn.	February, 1928	Chicago, Ill.
Natl. Assn. of Mfgrs.	Oct. 25–27, 1927	Chattanooga, Tenn.
Natl. Academy of Sciences	Oct. 18–20, 1927	Urbana, Ill.
Natl. Exposition of Power and Mech. Engineering	Dec. 5–10, 1927	New York City
Natl. Safety Council	Sept. 26–30, 1927	Chicago, Ill.
Optical Society of America	Oct. 20–22, 1927	Schenectady, N. Y.

American Ceramic Society

1928 Annual Meeting

Ambassador Hotel, Atlantic City, N.J.

February 5-11, inclusive, 1928

National Brick Manufacturers Association
Meeting Concurrently

The tentative program for meetings as agreed upon by the New Jersey Local Committee is as follows:

Sunday: Registration — President's Reception — Symphony Concert—Orchestra and Soloists—Dancing

Monday: 9:30 A.M. General Session
2:30-5:30 P.M. Division Meetings
8:30 P.M. Dinner Dance and Cabaret

Tuesday: 9:30 A.M.-12:30 P.M. Division Meetings
12:30-5:30 P.M. Division Meetings
8:30-10:00 P.M. Water Carnival

Wednesday: 9:30 A.M.-12:30 P.M. Division Meetings
2:30-5:30 P.M. General Meeting
7:30 P.M. Banquet

Thursday to Saturday, inclusive: Plant trips by Divisions in New Jersey, Pennsylvania, and Maryland.

LOCAL COMMITTEE, NEW JERSEY CLAY WORKERS ASSOCIATION

D. Parry Forst, *Chairman*
R. L. Clare
J. A. Williams
Frank W. Dinsmore
Geo. H. Brown
Fred A. Whitaker

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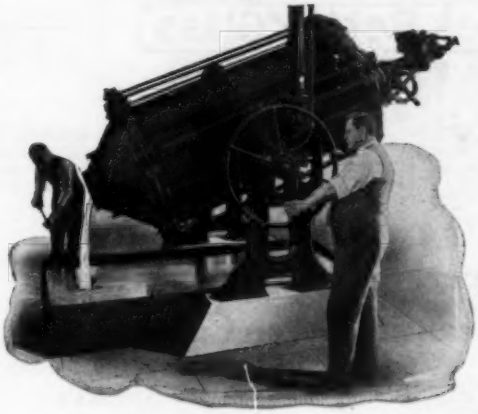

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Ingram-Richardson Corporation, Bayonne, N. J.
Grand Rapids Refrigerator Co., Grand Rapids, Mich.
Columbian Enameling & Stamping Co., Terre Haute, Ind.
Sheet Metal Products Company, Toronto, Canada.
Republic Metalware Company, Buffalo, N. Y.
Pacific Sanitary Mfg. Company, Richmond, California.
A. Weiskittel & Son Company, Baltimore, Md.
Malleable Iron Range Company, Beaver Dam, Wis.
Edison Electric Appliance Co., Inc., Chicago, Ill.
Welsh Tinplate & Metal Stpg. Co., Ltd., Llanelly, England.
Ernest Stevens, Limited, Cradley Heath, England.
Ward Leonard Electric Company, Mount Vernon, N. Y.
American Enameled Products Co., Chicago, Ill.
Michigan Porcelain Tile Works, Ionia, Michigan.
Stanley Insulating Company, Great Barrington, Mass.
Roesch Enamel Range Company, Belleville, Ill.
L. D. Caulk Company, Milford, Delaware.

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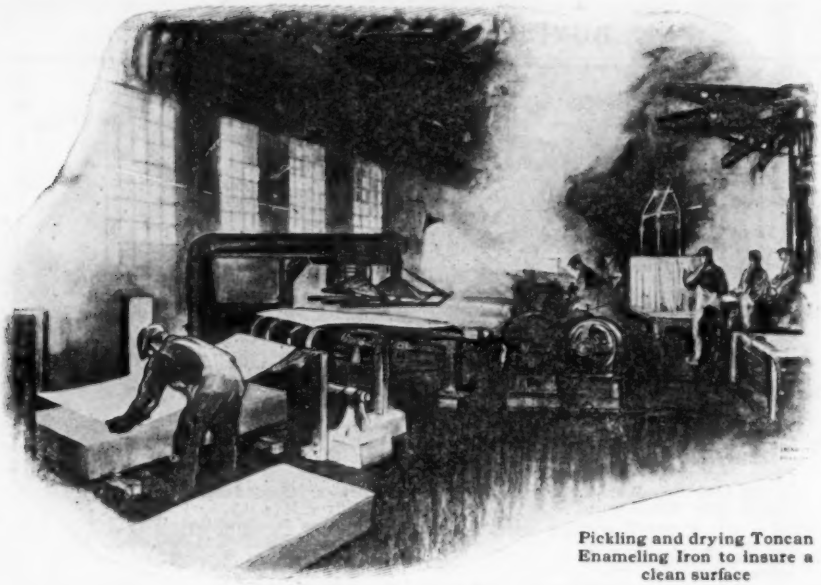

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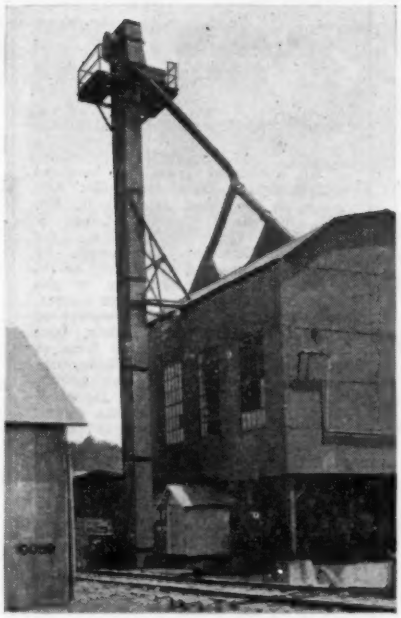

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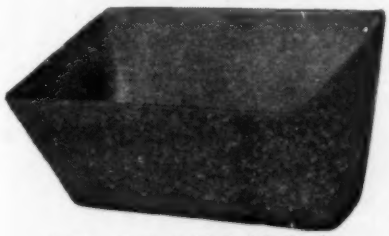

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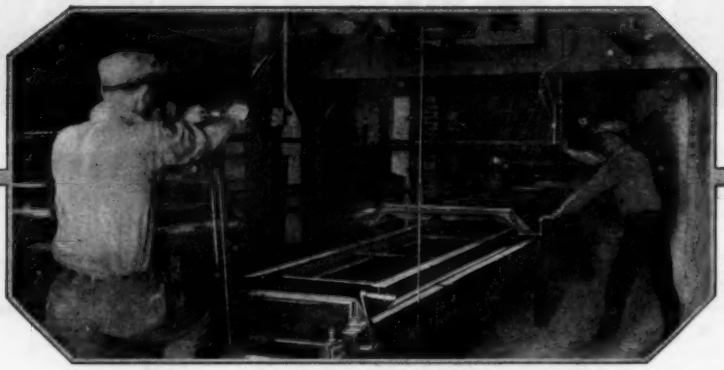

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Every day more and more people are making sure of enduring household articles by asking this question.

2725—2/c Page—Good Housekeeping—July ★

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You will readily see how enamelers who have standardized on ARMCO Ingot Iron are profiting by this retail demand. It is reflected back to them in the shape of increased production . . . . just another story of public preference being relayed back to the plant. Which in this instance is YOUR plant if you are one of the fortunate enamelers who use "pure iron."

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THE failure of a furnace to function properly often means the shut-down of an entire plant, and consequently heavy loss. Manufacturers who use gas are assured of continuous operation.

Difficult heat treating problems have been successfully solved by automatic gas-heated equipment.

Many new developments in gas-fired furnaces for various purposes have recently been made. They are well past the experimental stages, and claims made of performance can be substantiated with figures and reports from units already in operation.

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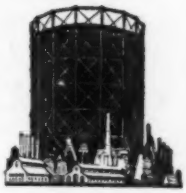

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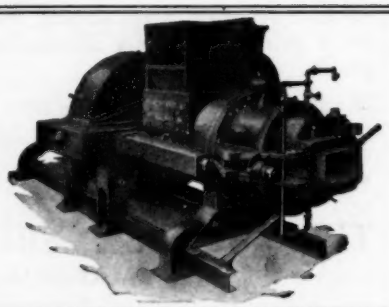

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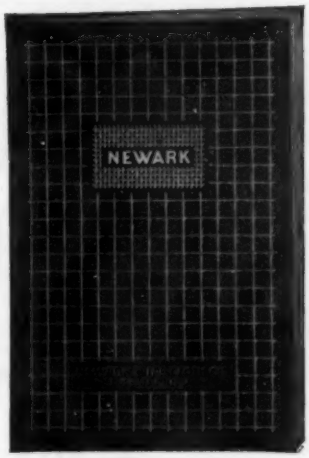

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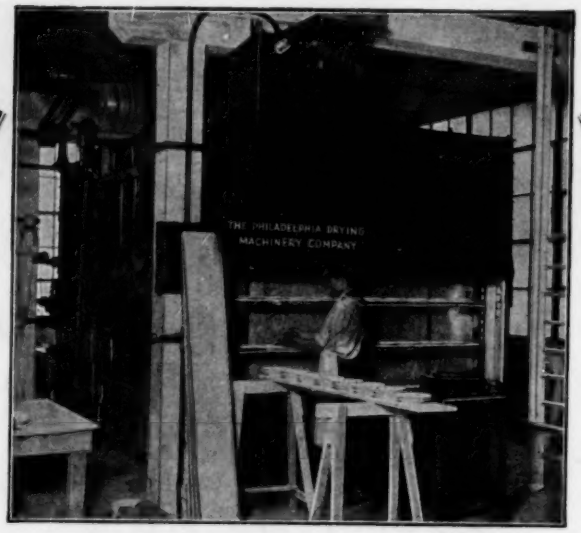

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MODERN production methods demand that the work be brought to the man by the use of automatic conveyors and continuous processes.

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Manufacturers of ceramic products appreciate a drying machine in which the drying time and conditions can be regulated, according to the size and weight of the materials,—and which take into consideration the varying characteristics of different kinds of clays.

"Hurricane" Dryers are the result of many years of experience, and, when furnished with Automatic Controls of Temperature and Humidity, give ideal drying every day.

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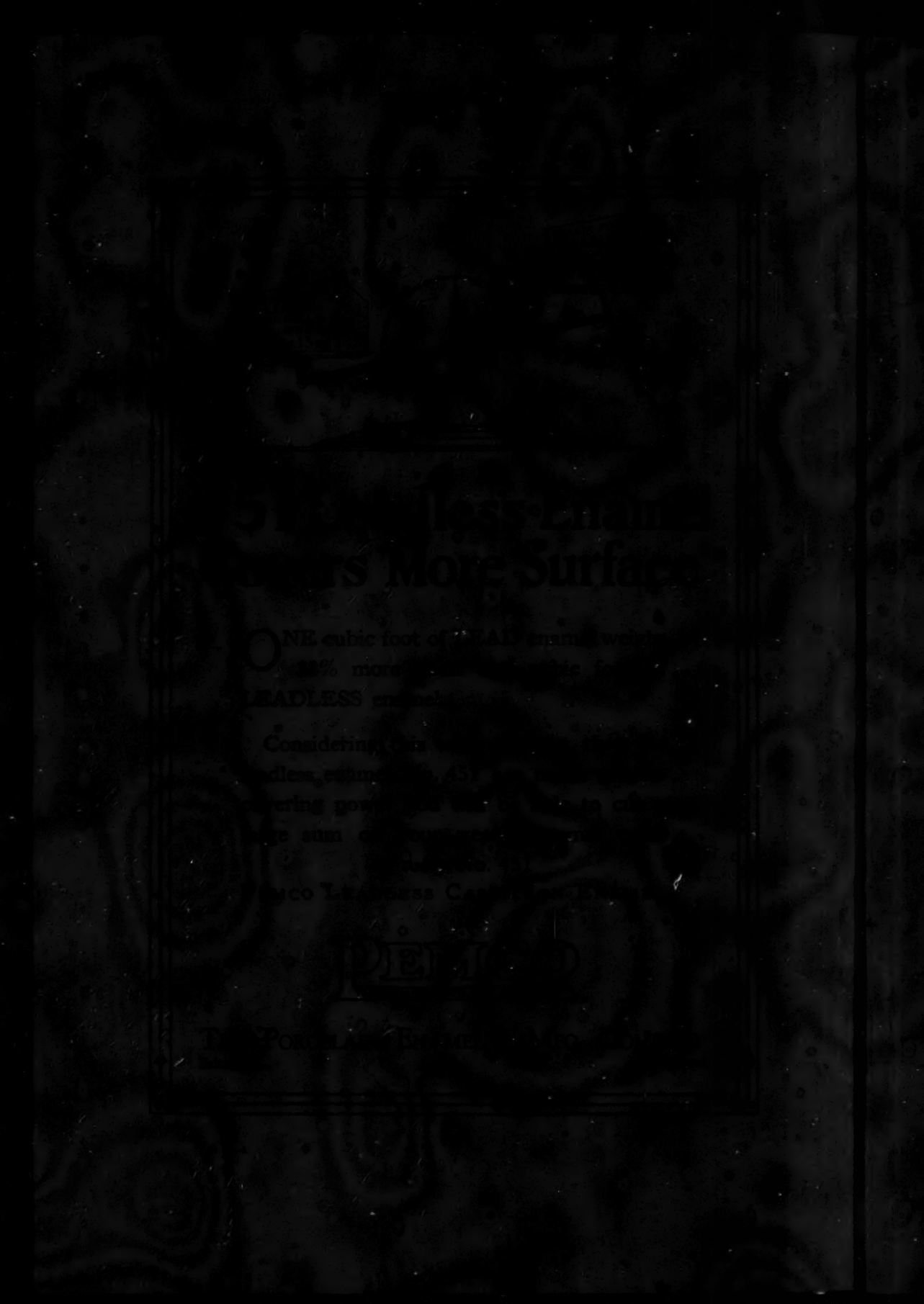
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